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SAND AND GRAVEL EXCAVATION;

PART 2: POWER SCRAPER, SLACKLINE CABLEWAY EXCAVATOR, AND HYDRAULIC GIANT

BY

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TABLE 15. - Power plants for power scrapers

Bucket capacity, cubic yards	Gasoline								Diesel								Electric hp.	
	Minimum				Maximum				Minimum				Maximum					
	Hp.	Cylinders	Stroke and bore	R.p.m.	Hp.	Cylinders	Stroke and bore	R.p.m.	Hp.	Cylinders	Stroke and bore	R.p.m.	Hp.	Cylinders	Stroke and bore	R.p.m.	Minimum	Maximum
1/3	22	4	3 1/2 by 4 1/2	1,200	-	-	-	-	-	-	-	-	-	-	-	-	15	
1/2	25	4	4 by 5	850	37	4	4 by 5	1,200	-	-	-	-	-	-	-	-	20	25
3/4	35	4	4 by 5	1,200	50	4	4 3/4 by 6	1,000	-	-	-	-	-	-	-	-	30	40
1	60	4	5 by 5 3/4	1,200	65	4	5 by 7	1,000	63	4	5 1/4 by 8	850	-	-	-	-	40	50
1 1/2	90	4	6 1/4 by 7	1,000	90	6	-	-	89	4	6 1/8 by 9 1/4	700	-	-	-	-	-	75
2	105	4	6 3/4 by 7	900	125	6	-	-	89	4	6 1/8 by 9 1/4	700	-	-	-	-	75	100
2 1/2	130	6	5 1/2 by 7	1,100	-	-	-	-	102	6	5 1/4 by 8	850	-	-	-	-	100	125
3	160	6	6 3/4 by 7	850	-	-	-	-	-	-	-	-	-	-	-	-	125	150
4	180	8	6 1/2 by 7	950	-	-	-	-	-	-	-	-	-	-	-	-	150	-
5	250	12	6 1/4 by 7	850	-	-	-	-	-	-	-	-	-	-	-	-	200	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	250	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	300	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	350	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	400	-

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As with other excavating equipment, the procedure is first to calculate the theoretical capacity without any delay factor and estimate working capacity from this figure by deducting a certain percentage which will represent in one lump the effect of all delay factors. The accuracy of the final results of such a calculation will depend entirely upon the accuracy with which the percentage reduction is determined.

Weather conditions cannot be foreseen in many parts of the country; in others they can be assumed as fairly constant for considerable periods of time.

The character of the material to be dug may vary with each excavation even though they are located in close proximity in the same deposit. Cemented gravel will retard production by offering more resistance to the scraper than loose sand. A deposit containing a large percentage of boulders likewise will be more difficult to excavate than material of comparatively uniform gradation. However, the power scraper is not limited in the distance it must be dragged to fill itself. It is potentially digging from the time it starts till it dumps. By that is meant it is moving over the deposit in digging position. It is true that the design of some scrapers causes them to lift and drag free when once loaded, but this does not alter the point under discussion.

The shovel dipper or dragline or crane bucket is in contact with the deposit for a limited time in which to load. If for any reason it is not filled in that time it must be returned for another attempt or swung with a partial load. The dragline can vary this by increasing the dragging distance. On the other hand, the power scraper, if not immediately filled, can usually complete its load as it proceeds without loss of time. Therefore cemented gravel or boulders do not offer the same delay to loading time as they do in other types of equipment. For instance, the scraper may fail to bite through a cemented deposit at one point on its first trip but will pick up its load beyond. Each subsequent trip, however, it will tear away more of the cemented material until finally it cuts clear through. In heavy boulders it may ride over them at the start but will pick up a few and string the others out along its path so that they can be caught on subsequent trips.

In excavation from wet pits the scraper seldom brings an overload to the dump. The buoyancy of the water usually acts to remove a pile pushed ahead of the scraper. In dry excavation it is not uncommon to see the scraper pushing as much ahead of it as it holds itself. This is especially true in digging banks in which the tail support is at a higher elevation than the head mast. Caved material runs into the trench ahead of the scraper and is pushed along by it.

Scrapers are designed differently for different kinds of excavation. Some have straight cutting edges while others have curved ones, and usually any type may be fitted with cutting teeth where needed. For difficult excavation heavier scrapers are needed which have more penetrating power.

The effect of delays due to accessory haulage equipment when required is the same as that for other types of excavators.

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In some scraper installations the position of the operator is such that he can see the scraper at all times. In others he may see it only for part of the trip, and in still others he cannot see it at all but must depend upon marks on the cable or hoist drum to tell him where it is. Obviously, a clear view of the scraper at all times promotes efficiency.

The skill and ability of the operator will have its effect on the capacity of a power scraper. This effect will be at a minimum in installations employing the power return. In this case he has only two motions to control, one pulling the scraper towards him and one pulling it away. Where the gravity return is used a certain amount of time is lost during manipulation of levers and regulation of tension on the track cable, and the effect of the efficiency of the operator will be more nearly comparable to that of the operator of a shovel or dragline.

From this discussion it is evident that the divergence between theoretical and working capacity for the power scraper will be less than for the power shovel, dragline, or crane. This does not mean, however, that it can be disregarded entirely. For instance, as the operator throws his hoist into motion at the loading point, there will be a lapse of time before the scraper starts to move, due to the necessity for taking up the slack in the load cable and bridle. In some material it may be necessary to move the scraper at reduced speed until it starts to load. When the dumping point is reached theoretically there is no appreciable delay in reversing the hoist and scraper motion. Practically, however, there is, because the hoist again has to take up the slack in the pull-back cable. In this case the slack is usually greater than with the load cable. When the tail support must be moved the design of the set-up with regard to facility of changing position will affect the time required in moving, and thus the ultimate capacity.

With installations in which the pull-back cable is threaded through a sheave in the top of the scraper, the loss of time due to taking up slack in the cables is reduced. Also by manipulating the brake on one drum against the clutch on the other, both load and pull-back cables may be kept taut.

With gravity-return installations the return speed is increased, but more time is required by the operator in manipulating the tension on the track cable. On long spans this can be done while the scraper is in motion. This enables the gravity-return scraper to operate over long spans with equal or greater economy.

The weight of a cubic yard of gravel varies in different geographic localities depending upon the compactness of the bank and the moisture content.

To estimate the capacity of a power scraper in which the empty is returned by the outhaul cable, the inhaul and outhaul speeds of table 14 are used to calculate a theoretical time cycle in seconds exclusive of any delay after the following manner:

$$\frac{\text{The hauling distance (feet) x 60}}{\text{The loading speed (f.p.m.)}} + \frac{\text{the hauling distance (feet) x 60.}}{\text{the outhaul speed (f.p.m.)}}$$

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In estimating the capacity of a gravity-return scraper the inhaul and average gravity-return speeds of table 14 are used in the same manner, but to the sum thus found must be added an arbitrary factor to cover the time lost in manipulating the tension on the track cable, etc. Experience has shown this to range from 15 to 25 seconds. The theoretical time cycle then becomes:

$$\frac{\text{The hauling distance (feet) x 60}}{\text{The loading speed (f.p.m.)}} + \frac{\text{the hauling distance (feet) x 60}}{\text{average gravity return speed (f.p.m.)}} +$$

the lost time factor in seconds.

The theoretical capacity in cubic yards per hour for any given haulage distance may then be computed as follows:

$$\frac{\text{Rated scraper capacity (cubic yards) x 3,600 seconds}}{\text{Time cycle (seconds)}}.$$

To facilitate computation table 16a has been compiled showing the theoretical time cycles for various lengths of haul using mechanical-return and table 16b for gravity-return installations. Using these time cycles, the theoretical capacity has been calculated and is presented in cubic yards per hour in table 17, a and b.

The corresponding estimated working capacities in tons per hour are shown in table 18,a and b. In arriving at these estimates the figures of the tables have been reduced first to tons by using 2,900 and 3,240 pounds per cubic yard for minimum and maximum. The minimum figures have then been reduced by 25 percent and the maximum by 10 percent. In other words, the author recognizes the difference in the weight of gravel from different sections of the country. He also estimates that delays other than lever manipulation will reduce the theoretical capacity 10 to 25 percent. The 25-percent reduction is designed to represent excavation in difficult ground and the 10-percent one in easily dug ground. Of course, instances will be found where the capacity may be reduced below the minimum figures given due to local conditions, but these ranges are believed to be fairly accurate in representing day-to-day production.

SLACKLINE CABLEWAY EXCAVATOR

The slackline cableway excavator, or "slackline," is a development of the power scraper. By adding a track cable and trolley to the power scraper the time required to return the empty scraper to the pit was speeded up. The next logical evolution was a similar speeding up of the inhaul trip. This could not be accomplished with the power scraper since the scraper must be dragged all the way on the ground because of its bottomless construction. The slackline, by utilizing the track cable and a bucket similar in construction to the dragline bucket, is enabled to speed up both the inhaul and outhaul trips.

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TABLE 16a. - Theoretical time cycles for mechanical-return power scrapers (seconds)

Haul, feet	Rated capacities of scrapers, cubic yards													
	1/3		1/2		3/4		1		1-1/2		2		2 1/2	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
100	45.	53	45	53	33.1	48.2	33.1	48.2	36.7	40	36.7	40	36.7	40
150	67.5	79.5	67.5	79.5	49.7	72.3	49.7	72.3	55	60	55	60	55	60
175	78.8	92.8	78.8	92.8	57.8	84.3	57.8	84.3	64.1	70	64.1	70	64.1	70
200	90	106.1	90	106.1	66.2	96.4	66.2	96.4	73.3	80	73.3	80	73.3	80
225	101.3	119.4	101.3	119.4	74.4	108.4	74.4	108.4	82.5	90	82.5	90	82.5	90
250	112.6	132.7	112.6	132.7	82.7	120.5	82.7	120.5	91.7	100	91.7	100	91.7	100
300	135	159.1	135	159.1	99.3	144.6	99.3	144.6	110	120	110	120	110	120
350	-----	-----	157.6	185.7	115.8	168.7	115.8	168.7	128.3	140	128.3	140	128.3	140
400	-----	-----	180	212.2	132.3	192.7	132.3	192.7	146.7	160	146.7	160	146.7	160
500	-----	-----	-----	-----	-----	-----	165.4	240.8	183.3	200	183.3	200	183.3	200
600	-----	-----	-----	-----	-----	-----	198.5	289.	220	240	220	240	220	240
700	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	256.7	280	256.7	280

Haul, feet	Rated capacities of scrapers, cubic yards (continued)													
	3		4		5		6		8		10		12	
	Min.	Max.	Min.		Min.		Min.		Min.		Min.		Min.	
100	36.7	40	40		40		40		40		40		40	
150	55	60	60		60		60		60		60		60	
175	64.1	70	70		70		70		70		70		70	
200	73.3	80	80		80		80		80		80		80	
225	82.5	90	90		90		90		90		90		90	
250	91.7	100	100		100		100		100		100		100	
300	110	120	120		120		120		120		120		120	
350	128.3	140	140		140		140		140		140		140	
400	146.7	160	160		160		160		160		160		160	
500	183.3	200	200		200		200		200		200		200	
600	220	240	240		240		240		240		240		240	
700	256.7	280	280		280		280		280		280		280	

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TABLE 16b. - Theoretical time cycles for gravity-return power scrapers (seconds)

Haul, feet	Rated capacities of scrapers, cubic yards													
	1/3		1/2		3/4		1		1 1/2		2		2 1/2	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
100	51.7	66	51.7	66	44.8	61.7	44.8	61.7	48.4	61.7	48.4	61.7	48.4	61.7
150	70	86.4	70	86.4	59.7	80	59.7	80	65	80	65	80	65	80
175	79.2	96.7	79.2	96.7	67.1	89.1	67.1	89.1	73.3	89.1	73.3	89.1	73.3	89.1
200	88.3	106.9	88.3	106.9	74.5	98.3	74.5	98.3	81.6	98.3	81.6	98.3	81.6	98.3
225	97.4	117.2	97.4	117.2	81.9	107.5	81.9	107.5	89.9	107.5	89.9	107.5	89.9	107.5
250	106.6	127.3	106.6	127.3	89.4	116.7	89.4	116.7	98.3	116.7	98.3	116.7	98.3	116.7
300	125	147.8	125	147.8	104.3	135	104.3	135	115	135	115	135	115	135
350	143.3	168.2	143.3	168.2	119.1	153.3	119.1	153.3	131.7	153.3	131.7	153.3	131.7	153.3
400	161.7	188.7	161.7	188.7	134	171.7	134	171.7	148.4	171.7	148.4	171.7	148.4	171.7
500	-----	-----	198.3	229.7	163.7	208.4	163.7	208.4	181.6	208.4	181.6	208.4	181.6	208.4
600	-----	-----	-----	-----	-----	-----	193.5	245	215	245	215	245	215	245
700	-----	-----	-----	-----	-----	-----	223.3	281.7	248.4	281.7	248.4	281.7	248.4	281.7
800	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	281.6	318.3	281.6	318.3
900	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1,000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Haul, feet,	Rated capacities of scrapers, cubic yards (continued)													
	3		4		5		6		8		10		12	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
100	48.4	61.7	51.7	61.7	51.7	61.7	51.7	61.7	51.7	61.7	51.7	61.7	51.7	61.7
150	65	80	70	80	70	80	70	80	70	80	70	80	70	80
175	73.3	89.1	79.1	89.1	79.1	89.1	79.1	89.1	79.1	89.1	79.1	89.1	79.1	89.1
200	81.6	98.3	88.3	98.3	88.3	98.3	88.3	98.3	88.3	98.3	88.3	98.3	88.3	98.3
225	89.9	107.5	97.5	107.5	97.5	107.5	97.5	107.5	97.5	107.5	97.5	107.5	97.5	107.5
250	98.3	116.7	106.7	116.7	106.7	116.7	106.7	116.7	106.7	116.7	106.7	116.7	106.7	116.7
300	115	135	125	135	125	135	125	135	125	135	125	135	125	135
350	131.7	153.3	143.3	153.3	143.3	153.3	143.3	153.3	143.3	153.3	143.3	153.3	143.3	153.3
400	148.4	171.7	161.7	171.7	161.7	171.7	161.7	171.7	161.7	171.7	161.7	171.7	161.7	171.7
500	181.6	208.4	198.4	208.4	198.4	208.4	198.4	208.4	198.4	208.4	198.4	208.4	198.4	208.4
600	215	245	235	245	235	245	235	245	235	245	235	245	235	245
700	248.4	281.7	271.7	281.7	271.7	281.7	271.7	281.7	271.7	281.7	271.7	281.7	271.7	281.7
800	281.6	318.3	308.3	318.3	308.3	318.3	308.3	318.3	308.3	318.3	308.3	318.3	308.3	318.3
900	-----	-----	345	355	345	355	345	355	345	355	345	355	345	355
1,000	-----	-----	381.7	391.7	381.7	391.7	381.7	391.7	381.7	391.7	381.7	391.7	381.7	391.7

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TABLE 17a. - Theoretical capacity, mechanical-return power scrapers, cubic yards per hour

Haul, feet	Rated capacities of scrapers, cubic yards													
	1/3		1/2		3/4		1		1 1/2		2		2 1/2	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
100	22.6	26.7	34	40	56	81.6	74.7	109	135	147	180	196	225	245
150	15.1	17.8	22.6	26.7	37.3	54.3	49.8	72.4	90	98.2	120	131	150	164
175	12.9	15.2	19.4	22.8	32	46.7	42.7	62.3	77.2	84.2	103	112	128	140
200	11.3	13.3	17	20	28	40.8	37.3	54.4	67.5	73.7	90	98.2	112	123
225	10	11.8	15.1	17.8	24.9	36.3	33.2	48.4	60	65.4	80	87.3	100	109
250	9	10.7	13.6	16	22.4	32.6	29.9	43.5	54	58.9	72	78.5	90	98.2
300	7.5	8.9	11.3	13.3	18.7	27.2	24.9	36.3	45	49.1	60	65.4	75	81.8
350	-----	-----	9.7	11.4	16	23.3	21.3	31.1	38.6	42.1	51.4	56.1	64.3	70
400	-----	-----	8.5	10	14	20.4	18.7	27.2	33.8	36.8	45	49	56.2	61.3
500	-----	-----	-----	-----	-----	-----	14.9	21.8	27	29.5	36	39.3	45	49.1
600	-----	-----	-----	-----	-----	-----	12.5	18.1	22.5	24.5	30	32.7	37.5	40.9
700	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	25.7	28	32.1	35.1

Haul, feet	Rated capacities of scrapers, cubic yards (continued)													
	3		4		5		6		8		10		12	
	Min.	Max.		Max.		Max.		Max.		Max.		Max.		Max.
100	270	294		360		450		540		720		900		1,080
150	180	196		240		300		360		480		600		720
175	154	168		206		257		308		412		514		617
200	135	147		180		225		270		360		450		540
225	120	131		160		200		240		320		400		480
250	108	118		144		180		216		288		360		432
300	90	98.3		120		150		180		240		300		360
350	78.2	84.2		103		129		154		206		257		309
400	67.5	73.7		90		113		135		180		225		270
500	54	59		72		90		108		144		180		216
600	45	49		60		75		90		120		150		180
700	38.5	42		51.5		64		77		103		129		154

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TABLE 17b. - Theoretical capacity, gravity-return power scrapers, cubic yards per hour

Haul, feet	Rated capacities of scrapers, cubic yards													
	1/3		1/2		3/4		1		1 1/2		2		2 1/2	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
100	18.2	23.2	27.3	34.8	43.8	60.3	58.3	80.3	87.5	112	117	149	146	186
150	13.9	17.1	20.8	25.7	33.7	45.2	45	60.3	67.5	83.1	90	111	112	138
175	12.4	15.1	18.6	22.7	30.3	40.2	40.4	53.6	60.6	73.7	80.8	98.2	101	123
200	11.3	13.6	16.8	20.4	27.5	36.2	36.6	48.3	55	66.2	73.3	88.2	91.5	110
225	10.2	12.3	15.4	18.5	25.1	33	33.5	44	50.2	60.1	67	80	83.7	100
250	9.4	11.2	14.1	16.9	23.1	30.2	30.8	40.5	46.3	55	61.7	73.2	77.2	91.5
300	8.1	9.6	12.2	14.4	20	25.9	26.7	34.5	40	47	53.3	62.6	66.7	78.3
350	7.1	8.4	10.7	12.6	17.6	22.7	23.5	30.5	35.2	41	47	54.7	58.7	68.3
400	6.4	7.4	9.5	11.1	15.7	20.2	21	26.9	31.5	36.4	42	48.5	52.4	60.6
500	-----	-----	7.8	9.1	13	16.5	17.3	22	25.9	29.7	34.5	39.6	43.2	49.6
600	-----	-----	-----	-----	-----	-----	14.7	18.6	22	25.1	29.4	33.5	36.7	41.9
700	-----	-----	-----	-----	-----	-----	12.8	16.1	19.2	21.7	25.6	29	32	36.4
800	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	22.6	25.6	28.3	32
900	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1,000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Haul, feet	Rated capacities of scrapers, cubic yards (continued)													
	3		4		5		6		8		10		12	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
100	175	223	233	278	292	349	350	418	467	557	584	696	700	835
150	137	166	180	203	225	257	270	308	360	412	450	514	540	617
175	121	147	162	182	202	228	242	273	323	364	404	455	485	546
200	110	132	146	163	183	204	220	245	293	326	366	408	439	489
225	100	120	134	148	168	185	201	222	268	295	335	369	402	443
250	92.7	110	124	135	154	169	185	203	247	270	308	338	370	405
300	80	94	107	115	133	144	160	173	213	230	267	288	320	346
350	70.5	82	94	100	117	126	141	151	188	201	235	251	282	302
400	63	72.8	84	89.2	105	111	126	134	168	178	210	223	252	267
500	51.8	59.5	69	72.6	86.4	91	104	109	138	145	173	181	207	218
600	44	50.2	58.7	61.3	73.5	76.7	88.2	92	118	123	147	153	176	184
700	38.4	43.5	51.2	52.8	64	66.2	76.7	79.5	102	106	128	133	153	159
800	34	38.4	45.2	46.7	56.5	58.4	67.8	70.	90.5	93.4	113	117	136	140
900	-----	-----	40.3	41.8	50.7	52.2	60.8	62.6	81.1	83.5	101	104	122	125
1,000	-----	-----	36.8	37.7	45	47.1	55.2	56.6	73.5	75.5	92	94	110	113

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TABLE 18a. - Estimated working capacity, mechanical-return power scrapers, tons per hour

Haul, feet	Rated capacities of scrapers, cubic yards													
	1/3		1/2		3/4		1		1 1/2		2		2 1/2	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
100	24	39	37	59	61	119	81	159	147	214	196	286	244	357
150	16	26	25	39	41	79	53	105	98	143	130	191	163	240
175	14	22	21	33	35	68	47	91	84	122	112	164	139	204
200	12	19	18	29	30	59	40	79	73	108	97	143	122	179
225	11	17	16	26	27	53	36	70	65	95	87	127	109	160
250	10	16	15	23	24	48	33	63	59	86	78	114	97	143
300	8	13	12	20	20	40	27	53	49	71	65	95	82	120
350	-----	-----	11	17	17	34	23	45	42	61	56	82	70	102
400	-----	-----	9	15	15	30	20	40	37	54	49	71	61	89
500	-----	-----	-----	-----	-----	-----	16	32	29	43	39	57	49	72
600	-----	-----	-----	-----	-----	-----	14	26	24	36	32	48	41	60
700	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	28	41	35	51

Haul, feet	Rated capacities of scrapers, cubic yards (continued)													
	3		4		5		6		8		10		12	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
100	294	430	392	525	490	657	588	788	785	1,050	980	1,315	1,175	1,575
150	196	286	261	350	327	438	392	525	522	700	653	875	785	1,050
175	167	245	224	300	279	374	336	450	448	600	560	750	670	900
200	147	214	196	263	245	328	294	394	392	525	490	657	587	788
225	130	191	174	233	218	292	261	350	348	467	435	585	522	700
250	117	172	157	210	196	263	235	315	312	420	392	525	470	630
300	97	144	130	175	163	219	196	263	261	350	326	437	392	525
350	85	122	112	150	140	188	167	225	224	300	279	375	336	450
400	73	107	97	131	123	165	147	196	196	262	244	328	294	393
500	59	86	78	105	97	131	117	157	157	210	196	263	235	315
600	49	71	65	88	82	110	97	131	130	175	163	219	196	262
700	42	61	56	75	70	94	84	112	112	150	140	188	167	225

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TABLE 18b. – Estimated working capacity, gravity-return power scrapers, tons per hour

Haul, feet	Rated capacities of scrapers, cubic yards: 1/3 Min.	1/3 Max.	1/2 Min.	1/2 Max.	3/4 Min.	3/4 Max.	1 Min.	1 Max.	1 1/2 Min.	1 1/2 Max.	2 Min.	2 Max.	2 1/2 Min.	2 1/2 Max.
100	0	34	30	51	49	88	63	117	95	163	127	217	159	272
150	15	25	23	38	37	66	49	88	73	122	97	162	122	202
175	13	22	20	33	33	59	44	78	66	107	88	143	110	179
200	12	20	18	30	30	53	40	70	60	96	80	129	100	160
225	11	18	17	27	27	48	36	64	55	88	73	117	91	146
250	10	16	15	25	24	44	33	59	50	80	67	106	84	133
300	9	14	13	21	22	38	29	50	43	69	58	91	72	114
350	8	12	12	18	19	33	26	44	38	60	51	80	64	100
400	7	11	10	16	17	29	23	39	34	53	46	71	57	88
500	-----	-----	8	13	14	24	19	32	28	43	37	58	47	72
600	-----	-----	-----	-----	-----	-----	16	27	24	37	32	49	40	61
700	-----	-----	-----	-----	-----	-----	14	23	21	32	28	42	35	53
800	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	25	37	31	47
900	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1,000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Haul, feet	Rated capacities of scrapers, cubic yards (continued): 3 Min.	3 Max.	4 Min.	4 Max.	5 Min.	5 Max.	6 Min.	6 Max.	8 Min.	8 Max.	10 Min.	10 Max.	12 Min.	12 Max.
100	190	325	254	405	318	508	380	610	508	810	635	1,020	760	1,215
150	149	242	196	296	245	375	294	450	392	600	488	750	587	900
175	131	214	176	266	220	333	263	400	352	530	438	663	527	796
200	120	193	159	238	199	297	239	357	319	475	397	594	477	713
225	109	175	146	216	183	270	219	324	291	430	364	538	437	645
250	100	160	135	196	167	246	200	296	268	393	335	492	400	590
300	87	137	116	167	145	210	174	252	232	335	290	420	348	505
350	76	120	102	147	127	184	153	220	204	292	255	366	306	440
400	68	106	91	130	114	162	137	195	183	259	228	326	275	390
500	56	87	75	106	94	132	113	159	150	212	188	264	225	318
600	48	73	64	89	80	112	96	134	128	180	160	223	191	268
700	42	63	56	77	70	96	83	116	111	155	139	194	167	232
800	37	56	49	68	61	85	74	102	98	136	123	171	148	204
900	-----	-----	44	61	55	76	66	92	88	122	110	151	133	182
1,000	-----	-----	40	55	49	69	60	82	80	110	100	137	120	165

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Except for the bucket, the slackline closely resembles the gravity-return power scraper in that it is a dual unit consisting of a head mast or tower and a tail anchorage between which is stretched a heavy track cable carrying a trolley from which the bucket is suspended. (See fig. 4.) Near the head tower this track cable is attached to one of a set of double or triple blocks, the other of which is fastened at the top of the head mast. (See fig. 5.) The tension cable threaded through these blocks is brought down to and wound around one drum of the hoist. The tail end of the track cable is threaded through a saddle sheave swung from a short steel or timber tower and is fastened to a bridle frame beyond. To the bridle frame are attached two cables connected with anchored hand winches for rapid shifting (fig. 4), or to a bridle cable anchored at each end (fig. 5). The tail tower is set on rollers to facilitate lateral movement as needed.

The inhaul cable runs from the hoist to a sheave in the head tower and thence to the bucket. When empty the bucket is returned by gravity.

The head tower may be either a single wooden or steel mast properly guyed or a more elaborately fabricated counterweighted structure, stationary or mounted on rollers, trucks, or a caterpillar chassis.

In order to provide elevation to enable the bucket to dig at the extreme end, the tail structure is usually a movable tower. However, if the topography is such that the proper elevation is available the tower may be eliminated and the track cable attached directly to the shifting bridle.

In operation the slackline digs material in the same manner as the power scraper except that the bucket when loaded is elevated by tightening the track cable and is hauled in while it is suspended in the air.

Starting with the track cable slackened and the bucket in the pit ready to dig, the sequence of operations is as follows: The operator starts the hoist drum to which the inhaul cable is attached and drags the bucket over the deposit until it is filled. He then engages the drum attached to the track cable and tightens it. By doing this he raises the bucket clear of the ground. Then he shifts to a higher hauling speed on the inhaul line and brings the bucket to the dumping point. Here a stop on the track cable engages the proper mechanism attached to the bucket, and it dumps automatically. The inhaul drum is then released, and the empty bucket returns by gravity over the still tight track cable. As the bucket approaches the digging point the track cable is slackened and the bucket lowered to the surface of the deposit for the next load.

Except for the time required to fill the bucket it is traveling clear of the ground suspended from the trolley on the track cable. This permits high speeds in both directions.

The slackline bucket like the power scraper, for each fixed position of head and tail supports travels in a straight line, and the excavatable area is little more than the width of the bucket at the bottom of its troughed path. As the trough deepens and the sides cave, the area widens. For greater

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area the tail support is moved laterally or both head and tail supports are so moved.

Owing to the heavy tension required on the track cable to lift the loaded bucket clear of the ground, the tail anchorage is usually of more substantial construction than with the power scraper.

While portable towers may be and are used for slackline excavators, they must be heavily counterbalanced to withstand the heavy tension on the track cable.

Excavation may be radial or rectangular as desired, the same as with the power scraper. The slackline may be used to strip the deposit, and because the bucket can be raised clear of the ground it can dump the overburden clear of the excavated gravel bank. The power scraper must drag its load over this bank, thus the edge of the pit is contaminated with material stripped from the more distant area. The scraper can, of course, return and clean this material from the bank in a second bite. The slackline, however, can do the whole job cleanly at one attempt.

Eventually a distance between head and tail supports will be reached beyond which it becomes uneconomical to operate, but until this distance is reached the slackline does its own hauling. Because of its ability to speed up both inhaul and return speeds the economic hauling distance is greater than with the power scraper. In fact, the slackline has a greater reach from a single set-up than any other type of excavating equipment. No fixed rule governs what this maximum economic distance will be. It will vary with the size of the scraper, the power applied to the load cable, the inhaul and gravity return speeds, the type of material to be dug, the plan of excavation, the design and weight of the bucket, and the tonnage required in a given time.

A second slackline may be set up to act as a transportation unit for the digging unit, or a power scraper may be so used. Moreover, any other type of transportation unit may be employed as with the power scraper.

The slackline may be used either for wet or dry excavation, and a considerable depth below grade may be reached. Large boulders and cemented gravel offer the same difficulty to the slackline as to the power scraper, although because of the guiding function of the track cable and trolley there is less opportunity for lateral slippage of the bucket.

The tail support need not be on the same level as the head mast. In fact, its top must be lower to provide an inclined track for gravity return. For this reason the slackline is not applicable to the excavation of high banks.

Structural Limitations

The slackline cableway excavator, like the power scraper, operates from the surface of the ground. Only the bucket and cables enter the pit. For this reason it may be used for either dry or wet excavation.

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Since the empty bucket is returned to the pit by gravity, the top of the tail support must be sufficiently below the top of the head mast to provide the necessary gradient. This limits the application of the slackline to subsurface pits, and it cannot be used to excavate bank deposits.

The height of head and tail supports will depend somewhat upon the topography of the deposit. In some cases a shorter head tower may be placed on an elevation. In others, the tail tower may be in a previous excavation also enabling a shorter head tower to be used. The height of the head tower, however, will depend largely upon the type of terminal used. If the material is delivered by the slackline direct to the treatment plant the tower must reach far enough above it to provide dumping height. This height may be greater than actually necessary to provde the required gradient. The tail tower, except where topography permits, must be high enough to clear the bucket and trolley assembly with the track cable taut. In any case, the difference in elevation between the tops of head and tail towers should be not less than 10 percent or more than 15 percent of the total span between them. Generally speaking, the minimum head-tower height should be one sixth to one tenth the total span.

The horizontal reach of the slackline is the greatest of all excavating equipment from a single set-up. In other words, the combination of high mechanical inhaul speed with gravity return enables the slackline to reach farther from a central point. However, there is an economic limit to this horizontal reach depending upon the local conditions, the size of the bucket, the hauling and return speeds, and the production required in a given time. The minimum span for slacklines is about 300 feet, but this may be extended to 1,500 or even 2,000 feet for the larger buckets.

As usually installed, the total span of a slackline is about 100 feet greater than the total length of excavation. This excess span is caused by the necessity for dumping space, treatment plant, and tail-tower clearance. Thus the average haul for a given width of excavations will be 50 feet greater than one half that width in straightline excavation. In radial operation the average haul will exceed 70 percent of the excavation width by the same 50 feet.

The depth below surface to which a slackline may operate will vary with local conditions of topography, character of material, etc., but may be approximated at 20 to 25 percent of the total span.

The height above surface to which the slackline will elevate its bucket for dumping depends upon the height of the head tower and factors affecting that height. In the larger bucket sizes more elevation is needed to clear the bucket and trolley assembly. For instance, while the 3 1/2-cubic yard bucket requires 36 feet of mast height above the dumping point the 1/3-cubic yard bucket requires only 22 feet.

Table 18 gives the horizontal and vertical ranges and traveling speeds as taken from various manufacturers' catalogs.

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TABLE 18. - Slackline cableway excavator working ranges

Bucket capacity, cubic yards	Operating span, feet		Average haul for operating span, feet		Height of mast for operating span, feet		Dumping heights for given mast heights, feet		Digging depth, intermediate span, feet	Digging speed, ft.p.m.	Inhaul speed, ft.p.m.		Average gravity return speed, ft.p.m.
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.			Min.	Max.	
1/3	300	500	200	300	50	70	28	48	80	200	400	600	1,000
1/2	300	600	200	350	50	80	28	58	90	200	400	600	1,000
3/4	300	700	200	400	50	90	24	64	130	200	600	600	1,000
1	300	800	200	450	50	100	22	72	140	200	600	600	1,000
1 1/2	300	1,000	200	550	50	120	18	88	160	200	600	1/900	1,300
2	300	1,200	200	650	50	125	18	93	180	200	600	1/900	1,300
2 1/2	300	1,400	200	750	50	130	16	96	200	200	600	2/1,350	1,300
3	300	1,500	200	800	50	140	16	106	210	200	600	2/1,350	1,300
3 1/2	300	1,500	200	800	50	140	14	104	210	200	600	2/1,350	1,300

1/ For average haul of 800 feet or more.
2/ For average haul of 1,000 feet or more.

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The slackline bucket is furnished in several different designs to fit different local conditions and the ideas of manufacturers or users. In general the same factors must be considered in adapting the design to local conditions as affect the dragline bucket. The ability to load depends upon the angle of the cutting teeth, the width of the cutting edge, the location of the point at which the loading bridle is attached, and the weight of the bucket. Loading ability is of greater importance with the slackline than with the power scraper because once lifted from the deposit on the inhaul the slackline has no further opportunity to complete a partial load as does the scraper.

Slackline buckets are dumped automatically while suspended from the track cable at the dumping point. Various arrangements for this purpose are provided by the manufacturers, of which some provide almost instantaneous discharge of the contents while others provide a gradual discharge.

Slackline excavators may be operated by gasoline, Diesel, electric, or steam power plants. The power plant consists of a multiple-drum hoist placed on the head tower or other convenient point. Slackline hoist requirements present problems peculiar to this type of equipment, and sometimes electric or steam power is preferred.

Table 19 gives the power requirements recommended by manufacturers.

Service Equipment Required

As usually supplied, the slackline excavator may be classed as belonging to the semiportable type of equipment. Either tower may be mounted on a movable chassis, but the head mast when used for gravel excavation is usually stationary. The power unit placed in or near the head mast does not require constant shifting of the power cables, water lines, or fuel lines.

The slackline is a transporting as well as excavating unit within the limits of its span. However, it can deliver to other types of haulage equipment if necessary, such as autotrucks, railway cars, or conveyor belts. Like the power scraper, delivery by the slackline to other types of conveyors ordinarily is accomplished through loading bins. A power scraper or second slackline may be used as an auxiliary haulage unit to serve the excavating unit. In this case the excavator dumps to a storage pile from which the second unit recovers its load.

Slackline excavators may be used as purely transportation units. By substituting flat skips for digging buckets, the slackline may be used to transport material from a power shovel, dragline, or crane. The excavating unit in this case loads the skips which are picked up by the slackline.

In sand and gravel excavation, however, the ordinary installation of slackline excavators requires the machine to dig the material and deliver it to the treatment plant without auxiliary haulage or excavation equipment.

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TABLE 19. - Power plants for slackline cableway excavators

Bucket capacity, cubic yards	Gasoline								Diesel								Electric	
	Minimum				Maximum				Minimum				Maximum				Hp.	
	Hp.	Cylinders	Stroke and bore	R.p.m.	Hp.	Cylinders	Stroke and bore	R.p.m.	Hp.	Cylinders	Stroke and bore	R.p.m.	Hp.	Cylinders	Stroke and bore	R.p.m.	Minimum	Maximum
1/3	35	4	4 by 5	1,200	-	-	-	-	-	-	-	-	-	-	-	-	30	-
1/2	35	-	-	-	50	4	4 3/4 by 6	1,100	-	-	-	-	-	-	-	-	30	40
3/4	65	-	-	-	70	4	5 by 7	1,100	63	4	5 1/4 by 8	850	-	-	-	-	50	60
1	100	-	-	-	100	4	6 1/2 by 7	1,000	89	4	6 1/8 by 9 1/4	700	-	-	-	-	75	-
1 1/2	125	-	-	-	145	6	6 1/2 by 7	950	102	6	5 1/4 by 8	850	-	-	-	-	100	-
2	-	-	-	-	180	8	6 1/4 by 7	950	-	-	-	-	-	-	-	-	150	-
2 1/2	-	-	-	-	250	8	6 1/4 by 7	850	-	-	-	-	-	-	-	-	200	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	300	-
3 1/2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	300	-

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Capacity

Theoretically the capacity of a slackline excavator depends upon the size of the bucket; the loading, inhaul, and gravity-return speeds; and the distance between digging point and dump.

The working capacity depends upon all of these factors and others. Local or seasonal weather conditions must be considered. However, since the slackline is operated by one man only and he can be protected from rain, local showers have not the same importance as delay factors as with other types of equipment. Other factors are the character of the material to be dug, whether excavation is wet or dry, the design and weight of the bucket, the service rendered by the accessory haulage equipment, if any, and the efficiency of the operator as shown by his proficiency in raising and lowering the track cable during inhaul and return time and in gaging loading time to obtain a full bucket and not prolong this time beyond that required for loading.

As with other types of equipment, the tabulation of theoretical capacity is valuable only in reaching a figure which may be reduced arbitrarily by a constant evaluated by local conditions and experience in order to arrive at a safe estimate of working capacity.

The character of the material to be dug varies widely over short distances at times and at others is quite constant throughout the deposit. The slackline will handle boulders and cemented gravel in the same manner as a power scraper if the track cable is left slack on the inhaul, but in the usual installation the bucket is lifted from the ground on the inhaul and then cannot push large boulders ahead of it in the digging trough.

In wet or dry pits the slackline bucket does not bring an overload to the dump in the same sense that the power scraper does. Bucket design varies with local conditions as it does for power scrapers.

The effect of delays due to accessory haulage equipment is the same as that with other types of excavating equipment except that it may be tempered by the use of storage bins or piles at the discharge end.

The operator of a slackline is usually so placed that he can see the bucket at all times. While it is true that he has only two major motions to control, as with the power scraper, namely the tension on the track cable and the operation of the inhaul cable, the manipulation and coordination of these motions require considerably more time and closer application than is necessary with the scraper. The track cable may be tightened while the bucket is being loaded, and it may be slacked off while the empty bucket is being returned by gravity. However, the inhaul drum of the slackline has two speeds, one slow for digging and one fast for transporting the loaded bucket to the dump. The transition from loading to inhaul speed is not instantly possible, and either during this change of speed or immediately before the track cable must be tightened. This necessitates the use of more than the two levers used on the power scraper. The coordination of these several movements and speed adjustments closely parallels the time and attention necessary in manipulating a shovel or dragline.

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The divergence between the theoretical and working capacities of the slackline will be greater than that with the power scraper and will more nearly correspond to that of the shovel and dragline.

There will be a small delay in picking up the slack in the load cable, but since there is no outhaul cable there is no slack to take up in starting the bucket on its return. The initial return movement will be slow but will accelerate as gravity overcomes the rolling friction of the trolley. This return speed must be decelerated by braking as the bucket approaches the digging point; thus the tabulated gravity-return speeds are average speeds calculated for various lengths of haul.

The release of the tension on the track cable to lower the bucket to the pit again requires the careful attention of the operator as did its tightening at the start of the cycle.

The time lost due to lever manipulation on slacklines has a somewhat different effect on capacity than with the shovel and dragline. The time required to loosen and tighten the track cable and operate the levers remains practically the same for individual operators except as they gain efficiency by experience. The length of haul, however, continually changes; hence the ratio of this lost time to the total cycle varies with the length of haul. For example, if the total cycle for a 450-foot haul is 100 seconds and the operating time loss 25 seconds, the ratio is 1 to 4. On a haul of 1,000 feet, the same equipment would have a total cycle of about 190 seconds. The operating time loss remaining as before at 25 seconds, the ratio is 1 to 7.6. Thus the effect of operating losses decreases as the hauling distance increases. Mathematical evaluation of this loss is difficult because of the personal element due to the efficiency of the operator.

The slackline bucket is similar in design to that of the dragline and the manner of loading is also similar. These buckets will usually load in 3 to 6 times their own length; therefore loading distances are assumed as used in dragline calculations, namely, 10 to 20 feet for the 1/3-, 1/2-, and 3/4-cubic yard buckets, and 15 to 30 feet for the 1-, 1 1/2-, 2-, 2 1/2-, 3-, and 3 1/2-cubic yard buckets.

In considering loading time it must be remembered that the slackline operator must load his bucket in one attempt. If the bucket is only partly loaded in that first try he cannot stop and return it for another bite as he can with the shovel or dragline. Therefore he must gage his loading time for such dragging distance as experience has proved sufficient in the material he is digging and not greater than is necessary to load the bucket fully. Since the bucket is considerable distance from him he cannot see this operation as readily as with the shovel or dragline. There is therefore a greater chance for hauling in a partly filled bucket with the slackline unless the loading time is extended beyond the average indicated by experience. Since the sum of inhaul and return times of the slackline exceeds the swing and return time of the shovel and dragline and constitutes most of the slackline cycle, the importance of loading the bucket fully at each trip becomes apparent. In this sense the efficiency of the operator becomes of even greater moment with the slackline than with the shovel or dragline.

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The first step required in computing the capacity of a slackline cableway excavator is determination of the theoretical time cycle. This is obtained by adding the time periods for each component operation in the complete cycle and an additional period representing the time lost in manipulating the levers and adjusting the tension on the track cable.

The component operating steps are loading, inhaul, and empty return. Loading time is a function of the speed of the loading cable and the distance necessary to drag the bucket to fill it and may be expressed as follows:

$$\frac{\text{Loading distance in feet}}{\text{Loading speed in f.p.m.}}.$$

Inhaul time is a function of the speed of the inhaul cable and the distance between the point at which loading ceases and the dump and may be expressed as follows:

$$\frac{\text{Hauling distance in feet}}{\text{Inhaul speed in f.p.m.}}.$$

The empty return time is a function of the distance between the dump and point at which loading starts and the speed at which the bucket returns to the pit. This speed is influenced by the length of span, gradient and arc of the track cable, frictional resistance of the trolley and unwinding inhaul cable and drum, and weight of the bucket. Obviously these factors will vary with each installation. For instance, on short spans the gradient of the track cable may be all downhill. On long spans the arc is downhill to a point ranging from one half to three fourths the total span and from there on to the tail tower the arc is uphill. Therefore on short spans the bucket returns at a constantly accelerating speed (except for the application of the brake), while on long spans the speed accelerates to the low point in the arc and then the momentum of the bucket carries it uphill against gravity. Frictional resistance will vary with the size, weight, and length of the inhaul cable and the mechanical construction of the equipment.

Therefore exact calculations for any individual installation would involve extended and intricate technical mathematics. Moreover, each different haulage distance would present a new set of calculations. Consequently the average return speeds as determined over a long period of experience and involving many time studies by various operators is used, as shown in table 18. These average speeds are 1,000 feet per minute for the 1/3-, 1/2-, 3/4-, and 1-cubic-yard buckets to 1,300 feet per minute for the larger sizes. However, on the extremely long spans such as 800 to 1,000 feet for the 1 1/2- and 2-cubic-yard buckets and 1,000 to 1,500 feet for the longer sizes an average of 1,200 feet per minute is used to compensate for the deceleration due to uphill climb on the long spans.

The gravity return time may be expressed thus:

$$\frac{\text{Return distance in feet}}{\text{Average return speed, f.p.m.}}.$$

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The operating time loss is a function of the efficiency of the operator and the hoist mechanism. This also depends upon many variables and cannot be calculated exactly. Experience and time studies show such losses to average 25 seconds per cycle and for the purpose of this paper are considered to range from 20 to 30 seconds.

The theoretical time cycle in seconds may then be calculated as follows:

$$\frac{\text{Loading distance (feet)} \times 60}{\text{Loading speed (f.p.m.)}} + \frac{\text{hauling distance (feet)} \times 60}{\text{inhaul speed (f.p.m.)}} +$$

$$\frac{\text{return distance (feet)} \times 60}{\text{average return speed (f.p.m.)}} + \text{operating time loss in seconds.}$$

These cycles have been calculated for various lengths of haul and standard speeds and are shown in table 20. As indicated by the footnote, additional calculations involve the use of maximum inhaul speeds (from table 18) with reduced return speeds for certain extremely long hauls, but these must be considered as special installations fitted to suitable operating conditions. They are presented merely to indicate the added capacity which may be obtained by higher inhaul speeds where conditions warrant their use.

The hourly capacity in cubic yards of a slackline for any given average hauling distance may be calculated from the time cycles of table 20 in the following manner:

$$\frac{\text{Rated bucket capacity (cubic yards)} \times 3{,}600}{\text{Time cycle (seconds)}}$$

The capacity thus obtained is still theoretical because it makes no allowance for losses due to unfilled buckets and other delays not included in the factor used in calculating table 20. The theoretical capacities in cubic yards per hour for various hauling distances are shown in table 21.

The figures given in table 21 are used as a basis from which to compute safe working capacities. Cubic yards are first converted to tons in which the weight of a cubic yard of sand and gravel is assumed to range from 2,900 to 3,240 pounds. These figures are then reduced by an arbitrary percentage based on experience. The slackline cableway has been found by time studies to have an average working capacity ranging from 60 to 75 percent of the theoretical as herein calculated. Thus the minimum tonnage figures found by conversion from table 21 are reduced by 40 percent and the maximum by 25 percent to obtain the estimated working capacities in tons per hour as shown in table 22.

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TABLE 20. - Theoretical time cycles for slackline cableway excavators (seconds)

Hauling distance, feet	Rated capacity of bucket, cubic yards																	
	1/3		1/2		3/4		1		1 1/2		2		2 1/2		3		3 1/2	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
200	54	75	54	75	53	67	53.5	69.5	50.7	66.7	50.7	66.7	50.7	66.7	50.7	66.7	50.7	66.7
300	70	96	70	96	69	83	69.5	85.5	65.3	81.3	65.3	81.3	65.3	81.3	65.3	81.3	65.3	81.3
350	78	106.5	78	106.5	77	91	77.5	93.5	72.6	88.6	72.6	88.6	72.6	88.6	72.6	88.6	72.6	88.6
400	86	117	86	117	85	99	85.5	101.5	79.9	95.9	79.9	95.9	79.9	95.9	79.9	95.9	79.9	95.9
450	94	125.5	94	127.5	93	107	93.5	109.5	87.2	103.2	87.2	103.2	87.2	103.2	87.2	103.2	87.2	103.2
500	102	138	102	138	101	115	101.5	117.5	94.5	110.5	94.5	110.5	94.5	110.5	94.5	110.5	94.5	110.5
550	110	148.5	110	148.5	109	123	109.5	125.5	101.8	117.8	101.8	117.8	101.8	117.8	101.8	117.8	101.8	117.8
600	118	159	118	159	117	131	117.5	133.5	109.1	125.1	109.1	125.1	109.1	125.1	109.1	125.1	109.1	125.1
650	126	169.5	126	169.5	125	139	125.5	141.5	116.4	132.4	116.4	132.4	116.4	132.4	116.4	132.4	116.4	132.4
700	134	180	134	180	133	147	133.5	149.5	123.7	139.7	123.7	139.7	123.7	139.7	123.7	139.7	123.7	139.7
750					141	155	141.5	157.5	131	147	131	147	131	147	131	147	131	147
800					149	163	149.5	165.5	138.3	154.3	138.3	154.3	138.3	154.3	138.3	154.3	138.3	154.3
High speed 900									1/ 112.8	1/ 128.3	1/ 112.8	1/ 128.3						
							165.5	181.5	152.9	168.9	152.9	168.9	152.9	168.9	152.9	168.9	152.9	168.9
High speed 1,000									1/ 124	1/ 139.5	1/ 124	1/ 139.5						
							181.5	197.5	167.5	183.5	167.5	183.5	167.5	183.5	167.5	183.5	167.5	183.5
High speed 1,500									1/ 135.2	1/ 150.7	1/ 135.2	1/ 150.7	2/ 117.6	2/ 132.8	2/ 117.6	2/ 132.8	2/ 117.6	2/ 132.8
													246.5	262.5	246.5	262.5	246.5	262.5
High speed													2/ 164.8	2/ 180	2/ 164.8	2/ 180	2/ 164.8	2/ 180

1/ Inhaul speed, 900 feet per minute.
2/ Inhaul speed, 1,350 feet per minute.

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TABLE 21. - Theoretical capacity, slackline cableway excavators, cubic yards per hour

Hauling distance, feet	Rated capacity of bucket, cubic yards																	
	1/3		1/2		3/4		1		1 1/2		2		2 1/2		3		3 1/2	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
200	16.0	22.2	24.0	33.3	40.6	51.0	51.8	67.3	81.0	107.0	108.0	142.0	135.0	178.0	162.0	213.0	189.0	249.0
300	12.5	17.1	18.7	25.7	32.5	39.1	42.1	51.8	66.4	82.7	88.6	110.0	111.0	138.0	133.0	165.0	155.0	193.0
350	11.3	15.4	16.9	23.1	29.2	35.1	38.5	46.5	61.0	74.4	81.3	99.2	102.0	124.0	122.0	149.0	142.0	174.0
400	10.3	13.9	15.4	20.9	27.3	31.8	35.5	42.1	56.3	67.6	75.0	90.1	93.9	113.0	113.0	135.0	131.0	158.0
450	9.4	12.8	14.1	19.2	25.2	29.0	32.9	38.5	52.4	61.9	69.8	82.6	87.2	103.0	105.0	124.0	122.0	145.0
500	8.7	11.8	13.0	17.6	23.5	26.7	30.7	35.5	48.9	57.1	65.2	76.2	81.5	95.3	97.8	114.0	114.0	133.0
550	8.1	10.9	12.1	16.4	22.0	24.8	28.7	32.9	45.9	53.0	61.1	70.7	76.4	88.5	91.7	106.0	107.0	124.0
600	7.6	10.2	11.4	15.3	20.6	23.1	27.0	30.7	43.2	49.5	57.6	66.0	71.9	82.5	86.4	99.0	101.0	116.0
650	7.1	9.5	10.6	14.3	19.4	21.6	25.4	28.7	40.8	46.4	54.4	61.8	68.0	77.3	81.6	92.8	95.2	108.0
700	6.7	9.0	10.0	13.4	18.4	20.3	24.1	27.0	38.7	43.7	51.6	58.2	64.4	72.8	77.3	87.3	90.2	102.0
750					17.4	19.2	22.9	25.4	36.7	41.2	49.0	55.0	61.2	68.7	73.5	82.5	85.7	96.2
800					16.6	18.1	21.8	24.1	35.0	39.0	46.7	52.0	58.3	65.0	70.0	78.1	81.7	91.1
High speed 900							19.8	21.8	1/ 42.1 32.0	1/ 47.8 35.3	1/ 56.1 42.6	1/ 63.8 47.1	53.3	58.9	64.0	70.6	74.6	82.5
High speed 1,000							18.2	19.8	1/ 38.7 29.4	1/ 43.5 32.2	1/ 51.6 39.3	1/ 58.0 43.0	49.0	53.7	58.9	64.5	68.7	75.3
High speed 1,500									1/ 35.8	1/ 40.0	1/ 47.8	1/ 53.3	2/ 67.8 34.3	2/ 76.6 36.5	2/ 81.4 41.2	2/ 91.8 43.8	2/ 95.0 48.0	2/ 107.0 51.1
High speed													2/ 50.0	2/ 54.6	2/ 60.0	2/ 65.5	2/ 70.0	2/ 76.5

1/ Inhaul speed, 900 feet per minute.
2/ Inhaul speed, 1,350 feet per minute.

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TABLE 22. - Estimated minimum and maximum working capacity, slackline cableway excavators, tons per hour

Hauling distance, feet	Rated capacity of bucket, cubic yards																	
	1/3		1/2		3/4		1		1 1/2		2		2 1/2		3		3 1/2	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
200	14	27	21	40	35	62	45	82	70	130	94	173	118	216	141	259	164	300
300	11	21	16	31	28	48	37	63	58	100	77	134	97	168	116	200	135	234
350	10	18	15	28	25	43	34	57	53	91	71	121	89	152	111	182	124	212
400	9	17	13	25	24	39	31	51	49	83	65	110	82	137	99	165	114	192
450	8	16	12	23	22	35	29	47	46	75	60	100	76	125	91	151	106	176
500	8	14	11	21	20	33	27	43	43	70	57	92	71	116	85	139	99	161
550	7	13	11	20	19	30	25	40	40	65	53	86	67	107	80	129	93	151
600	7	12	10	19	18	28	24	37	38	60	50	81	62	100	75	120	88	141
650	6	12	9	17	17	26	22	35	36	56	47	75	58	94	71	113	83	131
700	6	11	9	16	16	25	21	33	34	53	45	71	56	88	67	106	79	124
750					15	23	20	31	32	50	43	67	53	83	64	100	74	117
800					14	22	19	29	30	47	40	62	51	79	61	95	71	110
High speed									1/ 37	1/ 58	1/ 49	1/ 77						
900							17	27	28	43	37	57	46	72	56	86	65	100
High speed									1/ 34	1/ 53	1/ 45	1/ 71						
1,000							16	24	26	39	34	52	43	65	51	78	59	92
High speed									1/ 31	1/ 49	1/ 42	1/ 65	2/ 59	2/ 93	2/ 71	2/ 112	2/ 83	2/ 130
1,500													30	44	36	53	42	62
High speed													2/ 44	2/ 66	2/ 52	2/ 80	2/ 61	2/ 93

1/ Inhaul speed, 900 feet per minute.
2/ Inhaul speed, 1,350 feet per minute.

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HYDRAULIC GIANT OR MONITOR

The term "hydraulic" as used to define a mining method is entirely distinct from and should not be confused with excavation by the use of a hydraulic or pump dredge.

Hydraulic mining methods originated in the recovery of placer gravels containing gold. Under the proper conditions these methods are inexpensive and afford a good recovery. As applied to gold recovery, the term is loosely used to cover two distinct methods--"ground sluicing" and "hydraulicking." In ground sluicing the gold miner utilizes the erosive action of running water, either in cascading over the top of a gravel bank or so directed as to undercut the bottom of the bank. In hydraulicking the water is conducted to the bank through pipes under medium to high pressures and used to undercut and cave the bank. So far as the writer is aware ground-sluicing methods have never been used to recover commercial sand and gravel. Hydraulicking has been used for this purpose to a limited extent.

Pressure for the water used in hydraulicking can be obtained in two ways--either by tapping a source at a higher elevation or by pumping. The selection depends entirely upon the topography of the surrounding country. In mountainous areas sources of sufficient water supply can frequently be found in springs or streams situated higher up the slope from which the water can be carried to the vicinity of the gravel by ditches or pipe lines. In this way the natural fall is utilized to produce the necessary pressure or head at the hydraulic giant. In flat areas the head must be supplied by pressure pumps. Although a large quantity of water can be pumped for a comparatively low cost, it has seldom been found economical to pump water for placer-mining operations.

In a recent report by Gardner and Johnson[3/] the operating costs at a number of placer mines are given, from which table 23 has been abstracted to compare the cost of using pumps and natural head to supply pressure.

TABLE 23. - Comparison of placer mining operating costs

Mines using water from	Number of mines	Cubic yards of gravel excavated daily		Tons excavated per labor shift	Operating cost per ton
		Minimum	Maximum		
Natural head	26	40	500	41.25	$0.042
Pumps	3	18	500	56.00	.328

3/ Gardner, E. D., and Johnson, C. H., Placer Mining in the Western United States. Inf. Circ. 6787, Bureau of Mines, 1934, 89 pp.

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Table 23 shows that where the hydraulic water must be pumped the operating cost is greatly increased. This table is given merely to illustrate the difference in cost and not to condemn pumping for hydraulic purposes. Where local conditions permit, hydraulicking even with pumps may be cheap and effective.

Hydraulicking requires the use of hydraulic giants or monitors. These are essentially portable nozzles attached to the end of the water-supply pipe and having contracted orifices through which the water issues under pressure. In general they are similar to nozzles used on the ends of fire hose, although in detail the resemblance is small. The smaller sizes may be attached to a short length of hose for hand operation by one or more men. The larger sizes and those using high pressure are usually mounted on a portable base and have mechanical attachments to direct and deflect the issuing stream. One man operates them.

The giant consists of a universal joint usually constructed of two elbows working together, a spout or short tapered length of pipe, a nozzle, and a deflector. (See fig. 6.) The universal joint fastens to the end of the supply-pipe line and permits either vertical or horizontal movement of the spout. Deflectors are of two types. One consists of a ball-shaped flexible joint between spout and nozzle with a guiding arm attached. By turning this joint in one direction the flowing water deflects the giant in the opposite direction. Another type consists of a short length of pipe of larger diameter than, and loosely fitted over, the end of the nozzle. By manipulating it against the issuing stream the direction is changed just as with the ball joint. Attaching the giant to the pipe line counteracts the upward thrust of the stream, and where low pressures are used the downward thrust is balanced by a counterweight and lever fastened on top of the spout.

Excavation is accomplished by directing the stream of water against the foot of the gravel bank and undercutting it. The force of the pressure tears the gravel loose, and the expended water carries it to the sluice, ditch, or sump. Sometimes a second giant is employed to wash the gravel to the sluice, leaving the first for cutting only.

As with other methods of excavation, the character of the material excavated has an important bearing on the efficiency of the unit. In gravel containing a large amount of clay, excavation will be slower because of the time and water expended in breaking up the clay so that the gravel may be carried away by the water.

Cemented gravels require higher water pressures to break up the bond between particles of material in the bank. Once broken, however, such gravels may not require more water for sweeping to sumps or sluices than loose material of the same size and characteristics.

In heavily cemented gravels it may be necessary to churn-drill the banks and blast ahead of the giant.

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A flat bedrock under the gravel requires more pressure to sweep the gravel to the sluices than one on a slope; also a weathered or rough bedrock requires a greater pressure for sweeping. However, if the available pressure is fixed, a greater volume of water will be required to move the gravel over either a flat or rough bedrock.

The daily yardage produced from any particular gravel deposit is proportional to the quantity of water used and the pressure on the giant. While it may be advantageous to vary either pressure or volume or both with changes in the character of the bank or material, there is no advantage in increasing the pressure if the pressure used is sufficient to break down the bank as rapidly as the volume of the stream can transport it.

In general, lower pressures are used for washing the gravel to ditch or sump than for cutting the bank, but usually larger quantities of water are used because there must be sufficient water to carry the material away. Wherever gravel must be sluiced an appreciable distance it is customary to compute the water requirements for the flow in the sluices at 90 percent by volume, or (conversely) the material sluiced should constitute 10 percent solids the same as estimated for good pumping practice.

The proper pressure to use on a particular deposit can only be approximated before operation. Trial is the only accurate measure.

Gravel deposits may be opened at either the upper or lower elevation of a sloping bedrock, but usually the latter point is preferred.

The head at which water is supplied to giants ranges commonly from 50 to 400 feet.

While direct comparisons between hydraulicking and dredging methods are impossible because of the differences in mining application, the initial investment required for a hydraulic operation may be considerably less than for a dipper or ladder dredge although, because of distant water supply and long ditches or pipe lines, it may exceed that required for a simple pump dredge.

One of the principal items of initial cost is the expenditure necessary to provide a suitable source of water. This requires (1) the location of a suitable source at an elevation above the gravel such as to provide the necessary pressure head; (2) the construction of ditches, flumes, viaducts, or pipe lines to carry the water to the deposit; and (3) the construction of a reservoir near and above the deposit to receive the water from the ditch and transfer it to the pressure pipe line terminating at the giant. Obviously, the variety of conditions existing at different deposits makes impossible any estimate of the expenditure necessary until all local details are known.

Frequently it is necessary to convey water long distances for hydraulic mining, some gold placers bringing it as far as 30 to 40 miles through ditches. It is doubtful if it would pay in sand and gravel excavation to bring water over a few miles. At times flumes must be constructed to carry the water over

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valleys or rivers, or it may even have to be siphoned in pipe lines over elevations. Usually, however, ditches constructed on the surface are sufficient, but they must be as free from curves as possible and of even cross section. They may require plank lining to prevent loss of water through seepage or to reduce bank erosion. Seepage losses at times range from 5 to 20 percent.

Table 24 has been abstracted and condensed from Gardner and Johnson's report to show the calculated velocity and discharge for ditches of various cross section and slope.

TABLE 24. - Calculated velocity and discharge for ditches

Bottom width.....feet	1.0	2.0	3.0	4.0	5.0	6.0	8.0
Top width..... do	2.5	4.0	6.0	8.0	10.0	12.0	16.0
Depth..... do	.75	1.0	1.5	2.0	2.5	3.0	4.0
Area..... square feet	1.31	3.0	6.75	12.0	18.75	27.0	48.0
Hydraulic radius.....R	.42	.62	.93	1.24	1.55	1.86	2.48

Velocity of flow (feet per second)

Slope (feet per mile)							
2		0.49	0.68	0.86	1.02	1.18	1.48
4	0.50	.70	.97	1.23	1.46	1.68	2.10
6	.62	.86	1.20	1.51	1.79	2.07	2.58
8	.72	1.00	1.39	1.75	2.07	2.39	2.98
10	.80	1.12	1.56	1.96	2.33	2.68	3.33
12	.88	1.23	1.70	2.15	2.55	2.94	3.66
15	.99	1.37	1.91	2.40	2.85	3.28	4.07
20	1.14	1.58	2.20	2.77	3.29	3.79	4.71

Discharge (cubic feet per second)

2		1.47	4.59	10.32	19.1	31.9	71.0
4	0.66	2.10	6.55	14.76	27.4	45.4	100.8
6	.81	2.58	8.10	18.12	33.6	55.9	123.8
8	.94	3.00	9.38	21.00	38.8	64.5	143.0
10	1.05	3.36	10.53	23.52	43.7	72.4	159.8
12	1.15	3.69	11.48	25.68	47.8	79.4	175.7
15	1.30	4.11	12.89	28.80	53.4	88.6	195.4
20	1.49	4.74	14.85	33.24	61.7	102.3	225.6

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The ditch or flume discharges into a reservoir, which may be merely a large wood, steel, or concrete tank or a pond excavated on the surface. The difference in elevation between water source and reservoir has no bearing on the head supplied to the giant. This head must be obtained from the difference in elevation between reservoir and giant.

The reservoir performs two functions. It transfers water from the ditch to the pipe line and acts as a settling basin in which may be removed silt and sand picked up by the water in the ditches. Usually a settling basin is provided at the upper end of the ditch for removing such material from the water at the source.

The ditch should also be provided with adequate spillways to remove excess water as in floods.

Ditches usually range in slope from 4 to 8 feet per mile. The velocity of the water is seldom less than 1 foot per second and should not exceed 3 feet per second unless the banks of the ditch are protected against erosion.

Recommended velocities and side slopes for ditches in various types of soil are as follows:

	Feet per second	Horizontal to vertical
Loose sand	1	2 - 1
Sandy soil	2	1 1/2 - 1
Loam	3	1 1/2 - 1
Stiff clay or gravel	4	1 - 1
Coarse gravel or cobblestones	5	1 - 1
Cemented gravel or soft rock	6	1 - 1
Hard rock	10	0 - 1

The velocity given above is the mean velocity. Surface velocity may be 25 to 35 percent higher. The depth of water should not exceed three fourths the vertical depth of the ditch or from 1 to 3 feet of freeboard should be allowed.

Kutter's formula is usually used for finding the velocity of water in ditches and their capacity.

$$V = \frac{\frac{1.811}{N} + 41.65 + \frac{0.00281}{S}}{1 + \frac{N}{\sqrt{R}}\left(41.65 + \frac{0.00281}{S}\right)} \times \sqrt{R\,S},$$

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in which

V = mean velocity in feet per second.

N = a coefficient representing the roughness of the bottom and sides of the ditch.

S = sine of the slope (fall divided by length).

R = hydraulic radius (area of water section divided by perimeter of channel) in feet.

The usual value used for N for excavated ditches is 0.035. For concrete or rough plant lining 0.012 is used.

The water is conveyed from reservoir to giant through pipe. This may be of any type provided it is sufficiently strong to withstand the pressure derived from the head. Many placer mines use a slip joint pipe fitting together like the joints of stove pipe. Others use spiral riveted pipe with flange joints. Ordinary water pipe may also be used. Provision must be made with any type for expansion and contraction due to changes in temperature. Usually expansion joints are provided at intervals of 100 to 2,000 feet. Horizontal or vertical curves often permit the elimination of expansion joints.

The pressure on the pipe line depends upon the head or difference in elevation between intake and discharge. Each foot of head is the equivalent of 0.433 pound per square inch of pressure. For convenient reference table 25 has been compiled showing the pressure for various heads.....

TABLE 25. - Head and pressure equivalents

Head, feet	Pressure, pounds per square inch	Head, feet	Pressure, pounds per square inch	Head, feet	Pressure, pounds per square inch
1	0.433	10	4.33	100	43.3
2	.866	20	8.66	200	86.6
3	1.299	30	12.99	300	129.9
4	1.732	40	17.32	400	173.2
5	2.165	50	21.65	500	216.5
6	2.598	60	25.98	600	259.8
7	3.031	70	30.31	700	303.1
8	3.464	80	34.64	800	346.4
9	3.897	90	38.97	900	389.7

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If the available head is known, the corresponding pressure can be read from the table and the proper pipe selected from manufacturers' specifications. A factor of 4 should be allowed for safety, or, in other words, at 200-foot head the pressure is 86.6 pounds per square inch. The pipe should have a bursting strength of not less than 4 x 86.6, or 346.4, or, say, 350 pounds per square inch.

The installation of the pipe line should be as straight as possible, curves either horizontal or vertical should be avoided, and where necessary the pipe should be anchored securely. Steep slopes also require anchorage to prevent downhill creep from expansion and contraction with temperature changes. Where vertical curves are necessary they should be vented at the top to release accumulations of air. All silt and sand should be removed before the water enters the pipe line, otherwise under heavy pressures the giant will suffer severe wear and erosion. A nozzle worn out of round does not throw a clear, solid stream but tends to spray badly. Curved or unnecessarily long pipe lines decrease the effective hydraulic head available at the giant by increasing friction head.

The quantity of water delivered by a giant depends upon (1) the diameter of the pipe, (2) the effective hydraulic head, and (3) the size of the nozzle.

The flow of water through hydraulic giants may be calculated from the following formula:4/

$$Q = C\,A \sqrt{\frac{1}{1 - \left(\frac{d}{D}\right)^4}} \sqrt{2g\,H}$$

in which, Q = cubic feet of water per second,

A = area of the nozzle tip in square feet,

H = effective head at nozzle in feet,

C = 0.91 a coefficient of nozzle discharge,

D = diameter of the nozzle at the base,

d = diameter of the nozzle at the tip,

g = 32.16 acceleration due to gravity.

This formula may be simplified to the following:

$$Q = 8.02\,C\,B\,A\,\sqrt{H}$$

in which $\sqrt{2g}$ is removed from the radical and the expression $\sqrt{\frac{1}{1 - \left(\frac{d}{D}\right)^4}}$ is replaced by B.

4/ Schoder, E. W., Marks Mechanical Engineer's Handbook: 3d ed., 1930, p. 265.

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B is a coefficient used to correct for the change in the velocity of the water at the entrance to the base of the nozzle due to different sizes of supply pipe. The coefficient is empirically correct for the probable range of ratios d/D as encountered in practice.

For convenience the values of B for various ratios between the diameters of the base and tip of nozzle are given in table 26.

TABLE 26. - Values of B[1/]

d/D	B	d/D	B
0.1	1.00005	0.5	1.033
.2	1.0008	.6	1.072
.25	1.002	.67	1.116
.3	1.004	.7	1.146
.33	1.006	.75	1.210
.4	1.013	.8	1.301

1/ The correction factor is seen to be practically unity for any ratio d/D less than 0.3, therefore for such nozzles the following simpler formula may be used:

$$Q = 8.02\ C\ A\ \sqrt{H}.$$

The effective head at the nozzle is obtained by subtracting the friction head in the supply pipe from the static head. The static head is the difference in elevation in feet between the water surface in the supply reservoir and the base of the giant.

Before the friction head, and consequently the effective head, can be determined, the velocity of flow in the supply pipe must be known. This is calculated from the formula

$$V = \frac{Q}{A},$$

in which,

V = the velocity in feet per second.

Q = the flow in cubic feet per second.

A = the cross-sectional area of the pipe in square feet.

The discharge for any nozzle at any effective head can be obtained from the simplified formula (p. 81). Table 27, calculated from this formula, gives the quantity of water discharged from nozzles of various tip and base diameters at selected effective heads.

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TABLE 27. - Flow of water through hydraulic giants

Q, cubic feet per second $= 8.02\ C\ B\ A\ \sqrt{H}$; $C = 0.91$.

Nozzle tip		Nozzle base		Value of B	Effective head, feet							
					50	100	150	200	250	300	350	400
					Effective pressure, pounds per square inch							
					21.65	43.30	64.95	86.60	108.25	129.9	151.55	173.2
					Spouting velocity at nozzle, feet per second							
Diameter, inches	Area, square feet	Diameter, inches	Area, square feet		51-54	73-77	90-94	103-109	116-122	127-133	137-144	146-154
					Q	Q	Q	Q	Q	Q	Q	Q
1 1/8	0.0070	6	0.1963	1.0000	0.36	0.51	0.63	0.72	0.81	0.89	0.96	1.02
1 3/8	.0103	6	.1963	1.0000	.53	.75	.92	1.06	1.19	1.30	1.41	1.50
2	.0218	6	.1963	1.006	1.13	1.60	1.96	2.26	2.53	2.78	2.99	3.20
2	-	7	.2673	1.003	1.13	1.60	1.96	2.26	2.52	2.77	2.98	3.19
2	-	8	.3491	1.002	1.13	1.59	1.95	2.25	2.52	2.76	2.98	3.19
3	.0491	7	.2673	1.020	2.58	3.66	4.48	5.17	5.78	6.33	6.84	7.31
3	-	8	.3491	1.011	2.56	3.62	4.44	5.13	5.73	6.27	6.77	7.24
3	-	9	.4418	1.006	2.55	3.60	4.42	5.10	5.70	6.24	6.74	7.21
3	-	10	.5454	1.004	2.54	3.60	4.41	5.09	5.69	6.23	6.73	7.19
3	-	11	.6600	1.002	2.54	3.59	4.40	5.08	5.68	6.22	6.71	7.18
4	.0873	9	.4418	1.024	4.62	6.52	8.00	9.22	10.32	11.30	12.20	13.00
4	-	10	.5454	1.013	4.57	6.46	7.92	9.13	10.20	11.20	12.10	12.90
4	-	11	.6600	1.011	4.56	6.44	7.89	9.10	10.20	11.15	12.05	12.90
4	-	12	.7854	1.006	4.53	6.41	7.85	9.06	10.15	11.10	12.00	12.80
5	.1364	12	.7854	1.013	7.13	10.09	12.36	14.30	15.95	17.50	18.90	20.20
5	-	13	.9218	1.011	7.11	10.05	12.33	14.20	15.90	17.40	18.80	20.10
6	.1963	11	.6600	1.053	10.67	15.05	18.50	21.30	23.90	26.10	28.30	30.20
6	-	12	.7854	1.033	10.46	14.80	18.13	20.90	23.40	25.60	27.70	29.60
6	-	13	.9218	1.025	10.38	14.70	18.00	20.80	23.20	25.40	27.50	29.40
6	-	14	1.069	1.018	10.32	14.60	17.87	20.60	23.10	25.30	27.30	29.20
6	-	15	1.227	1.013	10.25	14.52	17.78	20.50	23.00	25.10	27.20	29.00
7	.2673	15	1.227	1.026	14.15	20.00	24.50	28.30	31.60	34.70	37.50	40.00
7	-	16	1.396	1.021	14.07	19.90	24.40	28.10	31.50	34.50	37.30	39.80
7	-	18	1.768	1.012	13.95	19.75	24.20	27.90	31.20	34.20	37.00	39.50
8	.3491	18	1.768	1.023	18.45	26.10	32.00	36.90	41.30	45.20	48.80	52.20

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The value of $C = 0.91$ is probably conservative, since several authorities give it as ranging from 0.9 to 0.997 or larger.

The loss in head due to friction in the water supply line is affected by the length of the line, the diameter of the pipe, the velocity of flow, and the roughness of the interior of the pipe. The latter is usually represented by a constant which is ascertained by observation for known conditions.

The friction head may be determined by the following formula:5/

$$F = \frac{L}{d} \times \frac{4V^2 + 5V - 2}{1,000},$$

in which

F = friction head in feet,

L = length of the pipe line in feet,

d = diameter of the pipe in inches,

V = velocity of flow in feet per second.

The divisor 1,000 is a constant representing the condition of the interior of clean, spiral, riveted pipe.

Table 28 gives the friction loss per 100 feet of various sizes of pipe. The loss is shown in terms of feet of head and pressure (pounds per square inch).

The quantity of water delivered by various giants, as given in table 27, is based on the "effective" head. This does not mean the available static head. For instance, if the available source of water supply is 200 feet above the giant, the effective head would not be 200 feet but something less than that, depending upon the head lost in overcoming friction in the supply pipe. Since the friction loss depends upon the length, diameter, and internal condition of the supply pipe as well as the velocity of flow, obviously the economic solution of any local water-supply problem depends upon proper design of the supply line to render the friction loss a minimum.

The flow of water through any pipe may be computed from the formula

$$Q = A V,$$

in which

Q = the quantity of water in cubic feet per second,

A = the cross-sectional area of the pipe in square feet,

V = the velocity of flow in feet per second.

5/ Cox, Wm., Kent's Mechanical Engineer's Pocket Book: 8th ed., 1913, p. 717.

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— — — — — friction loss, (F) and (P), per 100 feet of straight riveted pipe

F = feet of head = $\frac{L}{d} \times \frac{4\,v^2 + 5\,v - 2}{1{,}000}$; P = pounds per square inch = 0.433 F.

Velocity, feet per second	Pipe diameter, inches													
	6		8		10		12		14		16		18	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P
1	0.12	0.052	0.09	0.039	0.07	0.030	0.06	0.026	0.05	0.022	0.044	0.019	0.04	0.017
2	.40	.173	.30	.130	.24	.104	.20	.087	.17	.074	.15	.065	.13	.056
3	.82	.355	.61	.264	.49	.212	.41	.178	.35	.152	.31	.134	.27	.117
4	1.37	.593	1.02	.442	.82	.355	.68	.295	.59	.256	.51	.221	.45	.195
5	2.05	.888	1.54	.667	1.23	.533	1.03	.446	.88	.381	.77	.333	.68	.295
6	2.87	1.24	2.15	.930	1.72	.750	1.43	.619	1.23	.533	1.08	.468	.96	.416
7	3.82	1.65	2.86	1.24	2.29	.990	1.91	.827	1.64	.710	1.43	.620	1.27	.550
8	4.90	2.12	3.67	1.59	2.94	1.28	2.45	1.06	2.10	.910	1.84	.796	1.63	.706
9	6.12	2.65	4.59	2.00	3.67	1.59	3.06	1.33	2.62	1.14	2.30	.996	2.04	.884
10	7.48	3.24	5.60	2.43	4.48	1.94	3.73	1.62	3.20	1.39	2.80	1.21	2.49	1.08
11	8.95	3.88	6.72	2.91	5.37	2.33	4.47	1.94	3.84	1.66	3.36	1.46	2.98	1.29
12	10.6	4.59	7.92	3.43	6.34	2.75	5.28	2.29	4.53	1.96	3.96	1.72	3.52	1.53
13	12.3	5.33	9.24	4.00	7.39	3.20	6.16	2.67	5.28	2.29	4.62	2.00	4.11	1.78
14	14.2	6.15	10.6	4.59	8.52	3.70	7.10	3.08	6.08	2.63	5.32	2.30	4.73	2.05
15	16.2	7.02	12.1	5.22	9.73	4.22	8.10	3.51	6.95	3.01	6.08	2.64	5.40	2.34
16	18.4	7.97	13.8	5.98	11.0	4.77	9.18	3.98	7.87	3.41	6.88	2.98	6.12	2.65
17	20.7	8.96	15.5	6.71	12.4	5.37	10.3	4.46	8.86	3.84	7.74	3.35	6.88	2.98
18	23.1	10.0	17.3	7.50	13.8	5.98	11.5	4.98	9.90	4.29	8.65	3.75	7.69	3.33
19	25.6	11.1	19.2	8.31	15.4	6.67	12.8	5.60	11.0	4.77	9.60	4.16	8.54	3.70
20	28.3	12.3	21.2	9.18	17.0	7.36	14.2	6.15	12.1	5.24	10.6	4.59	9.44	4.09
21	31.1	13.5	23.3	10.1	18.7	8.10	15.6	6.75	13.3	5.76	11.7	5.06	10.4	4.50
22	34.1	14.8	25.6	11.1	20.4	8.83	17.0	7.36	14.6	6.32	12.8	5.54	11.4	4.94
23	37.2	16.1	27.9	12.1	22.3	9.66	18.6	8.05	15.9	6.88	13.9	6.02	12.3	5.33
24	40.4	17.5	30.3	13.1	24.2	10.5	20.2	8.75	17.3	7.50	15.2	6.58	13.5	5.84
25	43.7	18.9	32.8	14.2	26.2	11.4	21.9	9.47	18.8	8.14	16.4	7.10	14.6	6.32
26	47.2	20.5	35.4	15.3	28.3	12.3	23.6	10.2	20.2	8.74	17.7	7.66	15.7	6.80
27	50.8	22.0	38.1	16.5	30.5	13.2	25.4	11.0	21.8	9.44	19.1	8.27	17.0	7.36
28	54.6	23.6	41.0	17.8	32.7	14.2	27.3	11.8	23.4	10.2	20.5	8.87	18.2	7.88
29	58.4	25.3	43.8	19.0	35.1	15.2	29.3	12.7	25.1	10.9	21.9	9.48	19.5	8.44
30	62.5	27.1	47.0	20.4	37.5	16.3	31.2	13.5	26.8	11.6	23.5	10.2	20.8	9.00

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TABLE 28. - Friction loss (F) and (P), per 100 feet of straight riveted pipe (Continued)

F = feet of head = $\frac{L}{d} \times \frac{4V^2 + 5V - 2}{1{,}000}$; P = pounds per square inch = 0.433 F.

Velocity, feet per second	Pipe diameter, inches													
	20		24		28		30		32		34		36	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P
1	0.035	0.015	0.03	0.013	0.025	0.011	0.023	0.010	0.022	0.009	0.02	0.009	0.02	0.009
2	.12	.052	.10	.043	.09	.039	.08	.035	.08	.035	.07	.030	.07	.030
3	.24	.104	.21	.091	.17	.074	.16	.069	.15	.065	.14	.060	.14	.060
4	.41	.178	.34	.147	.29	.126	.27	.117	.26	.113	.24	.104	.23	.100
5	.62	.269	.51	.221	.44	.191	.41	.178	.39	.169	.36	.156	.34	.147
6	.86	.373	.72	.312	.61	.264	.57	.247	.54	.234	.50	.217	.48	.208
7	1.15	.498	.95	.412	.82	.355	.76	.329	.72	.312	.67	.290	.64	.277
8	1.47	.636	1.22	.528	1.05	.455	.98	.425	.92	.399	.86	.373	.82	.355
9	1.84	.796	1.58	.684	1.31	.568	1.22	.528	1.15	.498	1.08	.468	1.02	.442
10	2.24	.970	1.87	.810	1.60	.693	1.49	.645	1.40	.606	1.32	.572	1.25	.542
11	2.69	1.17	2.24	.970	1.92	.832	1.79	.775	1.68	.728	1.58	.684	1.49	.645
12	3.17	1.37	2.64	1.14	2.26	.978	2.11	.914	1.98	.857	1.87	.810	1.76	.762
13	3.70	1.60	3.08	1.34	2.64	1.14	2.46	1.07	2.31	1.00	2.17	.940	2.05	.888
14	4.26	1.85	3.55	1.54	3.08	1.34	2.84	1.23	2.66	1.15	2.51	1.09	2.37	1.03
15	4.86	2.11	4.05	1.76	3.47	1.50	3.24	1.40	3.04	1.32	2.86	1.24	2.70	1.17
16	5.50	2.38	4.59	1.99	3.93	1.70	3.67	1.59	3.44	1.49	3.24	1.40	3.06	1.33
17	6.20	2.69	5.16	2.24	4.42	1.92	4.13	1.75	3.87	1.68	3.65	1.58	3.44	1.49
18	6.92	3.00	5.77	2.50	4.94	2.14	4.61	2.00	4.33	1.88	4.07	1.76	3.84	1.66
19	7.68	3.33	6.40	2.77	5.49	2.38	5.12	2.22	4.80	2.08	4.52	1.96	4.27	1.85
20	8.50	3.68	7.08	3.07	6.06	2.63	5.66	2.45	5.31	2.30	5.00	2.17	4.72	2.05
21	9.34	4.05	7.78	3.41	6.67	2.89	6.22	2.70	5.84	2.53	5.50	2.38	5.18	2.24
22	10.2	4.42	8.52	3.70	7.30	3.16	6.82	2.96	6.39	2.77	6.02	2.61	5.68	2.26
23	11.2	4.85	9.30	4.06	7.96	3.45	7.44	3.22	6.97	3.02	6.56	2.84	6.20	2.69
24	12.1	5.24	10.1	4.37	8.65	3.75	8.08	3.50	7.57	3.28	7.13	3.09	6.73	2.92
25	13.1	5.67	10.9	4.72	9.37	4.06	8.75	3.79	8.20	3.55	7.72	3.34	7.30	3.16
26	14.2	6.14	11.8	5.12	10.1	4.37	9.45	4.10	8.86	3.84	8.34	3.61	7.87	3.41
27	15.3	6.62	12.7	5.50	10.9	4.72	10.2	4.42	9.53	4.13	8.97	3.88	8.47	3.67
28	16.4	7.10	13.7	5.93	11.7	5.07	10.9	4.72	10.2	4.42	9.63	4.17	9.10	3.94
29	17.5	7.58	14.6	6.32	12.5	5.41	11.7	5.07	11.0	4.77	10.3	4.46	9.74	4.22
30	18.8	8.14	15.6	6.76	13.4	5.80	12.5	5.42	11.7	5.07	11.0	4.76	10.4	4.50

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Table 29, computed from this formula, shows the quantity flowing in pipes of various diameters at various velocities. Quantities are given in both cubic feet per second and gallons per minute.

Tables 27, 28, and 29 have been computed to enable an operator to select the proper size of giant and supply line to meet his local conditions.

Various other formulas are given by authorities on hydraulic operations, and they are published in standard handbooks to which the reader is referred for more detailed technical information.

Operating Limitations

Hydraulic giants require water under pressure produced by natural head or from pumps.

The distance from the bank at which they may be set up and do effective work depends upon the pressure at the nozzle and the character of the gravel. It ranges from 40 to 450 feet but usually is from 100 to 300 feet.

Although table 27 shows certain tip and base diameters for giants various other combinations may be used. Most giants may be fitted with various sized tips. Therefore, when starting operations a larger unit than initial production requires may be installed and fitted with a smaller nozzle. As tonnage requirements increase, larger nozzles may be used up to the capacity of the giant.

Where the principal duty of the giant is to cut the bank or where the bank is tight or cemented, smaller nozzles with higher pressures are used. Larger nozzles with less pressure are used for washing or sweeping.

At times two similar giants are used, one with a small nozzle for cutting and one with a larger nozzle for sweeping.

One large giant will usually do more work with the same quantity of water than two smaller ones.

Auxiliary Equipment

The hydraulic giant requires a relatively large water supply, preferably under natural head. Where the topography permits, the water may be brought from the source to within a short distance of the giant in ditches. Where sufficient elevation is not obtainable near the giant, pipes must be used.

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TABLE 29. - Flow, (Q) and (G), in straight riveted pipe

Q = cubic feet per second = A V; G = gallons per minute = 450 Q

Velocity, feet per second	Pipe diameter, inches													
	6		8		10		12		14		16		18	
	Q	G	Q	G	Q	G	Q	G	Q	G	Q	G	Q	G
1	0.1963	88	0.3491	157	0.5454	245	0.7854	353	1.069	481	1.396	628	1.768	796
2	.3926	176	.6982	314	1.091	491	1.571	707	2.138	962	2.292	1,256	3.536	1,592
3	.5889	265	1.047	471	1.636	736	2.356	1,060	3.207	1,443	4.188	1,884	5.304	2,386
4	.7852	355	1.396	628	2.182	982	3.142	1,414	4.276	1,924	5.584	2,512	7.072	3,184
5	.9815	442	1.746	785	2.727	1,227	3.927	1,767	5.345	2,405	6.980	3,140	8.840	3,980
6	1.178	530	2.095	943	3.272	1,473	4.712	2,120	6.414	2,886	8.376	3,770	10.61	4,776
7	1.374	618	2.444	1,100	3.818	1,718	5.498	2,475	7.483	3,367	9.772	4,400	12.38	5,570
8	1.570	706	2.793	1,247	4.363	1,964	6.283	2,828	8.552	3,848	11.17	5,025	14.14	6,360
9	1.767	795	3.142	1,414	4.909	2,210	7.069	3,180	9.621	4,330	12.56	5,650	15.91	7,160
10	1.963	883	3.491	1,572	5.454	2,453	7.854	3,533	10.69	4,810	13.96	6,280	17.68	7,956
11	2.159	972	3.840	1,728	5.999	2,700	8.639	3,888	11.76	5,290	15.36	6,910	19.45	8,760
12	2.356	1,060	4.189	1,885	6.545	2,945	9.425	4,240	12.83	5,770	16.75	7,540	21.22	9,550
13	2.552	1,150	4.538	2,042	7.090	3,190	10.21	4,593	13.90	6,250	18.15	8,170	22.98	10,350
14	2.748	1,237	4.887	2,200	7.636	3,435	11.00	4,950	14.97	6,730	19.54	8,800	24.75	11,140
15	2.944	1,325	5.237	2,357	8.181	3,680	11.78	5,300	16.04	7,215	20.94	9,430	26.52	11,940
16	3.141	1,414	5.586	2,514	8.726	3,926	12.57	5,653	17.10	7,695	22.34	10,050	28.29	12,730
17	3.337	1,502	5.935	2,670	9.272	4,172	13.35	6,006	18.17	8,175	23.73	10,680	30.06	13,530
18	3.534	1,590	6.284	2,827	9.817	4,420	14.14	6,360	19.24	8,660	25.13	11,310	31.82	14,320
19	3.730	1,678	6.633	2,985	10.36	4,660	14.92	6,710	20.31	9,140	26.52	11,940	33.59	15,110
20	3.927	1,763	6.982	3,142	10.91	4,910	15.71	7,065	21.38	9,620	27.92	12,560	35.36	15,910
21	4.123	1,850	7.331	3,300	11.45	5,155	16.49	7,420	22.45	10,100	29.32	13,190	37.13	16,710
22	4.319	1,943	7.680	3,457	11.99	5,400	17.28	7,775	23.52	10,580	30.71	13,820	38.90	17,500
23	4.516	2,030	8.029	3,612	12.54	5,645	18.06	8,125	24.59	11,060	32.11	14,450	40.66	18,300
24	4.712	2,120	8.378	3,770	13.09	5,890	18.85	8,480	25.66	11,540	33.50	15,080	42.43	19,100
25	4.908	2,200	8.727	3,927	13.64	6,135	19.64	8,835	26.73	12,020	34.90	15,710	44.20	19,890
26	5.104	2,300	9.076	4,085	14.18	6,380	20.42	9,190	27.79	12,500	36.30	16,340	45.97	20,690
27	5.300	2,390	9.426	4,242	14.73	6,630	21.21	9,543	28.86	12,980	37.69	16,960	47.74	21,480
28	5.497	2,470	9.775	4,400	15.27	6,870	21.99	9,900	29.93	13,460	39.09	17,590	49.50	22,280
29	5.693	2,560	10.12	4,557	15.82	7,110	22.78	10,250	31.00	13,950	40.48	18,220	51.27	23,080
30	5.889	2,650	10.47	4,710	16.36	7,360	23.56	10,600	32.07	14,430	41.88	18,840	53.04	23,870

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TABLE 29. - Flow, (Q) and (G), in straight riveted pipe (Continued)

Q = cubic feet per second = A V; G = gallons per minute = 450 Q

Velocity, feet per second	Pipe diameter, inches													
	20		24		28		30		32		34		36	
	Q	G	Q	G	Q	G	Q	G	Q	G	Q	G	Q	G
1	2.182	982	3.142	1,414	4.276	1,925	4.909	2,209	5.585	2,513	6.305	2,837	7.069	3,181
2	4.364	1,964	6.284	2,928	8.552	3,850	9.818	4,418	11.17	5,026	12.61	5,674	14.14	6,362
3	6.546	2,946	9.426	4,242	12.83	5,775	14.73	6,627	16.76	7,539	18.92	8,511	21.21	9,543
4	8.728	3,928	12.57	5,656	17.10	7,700	19.64	8,836	22.34	10,050	25.22	11,350	28.28	12,720
5	10.91	4,910	15.71	7,070	21.38	9,625	24.55	11,050	27.93	12,570	31.53	14,190	35.35	15,910
6	13.09	5,892	18.85	8,483	25.66	11,550	29.45	13,250	33.51	15,080	37.83	17,020	42.41	19,090
7	15.27	6,874	21.99	9,897	29.93	13,480	34.36	15,460	39.10	17,590	44.14	19,860	49.48	22,270
8	17.46	7,856	25.14	11,310	34.21	15,400	39.27	17,670	44.68	20,100	50.44	22,700	56.55	25,450
9	19.64	8,838	28.28	12,725	38.48	17,330	44.18	19,880	50.27	22,620	56.75	25,530	63.62	28,630
10	21.82	9,820	31.42	14,140	42.76	19,250	49.09	22,090	55.85	25,130	63.05	28,370	70.69	31,810
11	24.00	10,800	34.56	15,550	47.04	21,180	54.00	24,300	61.44	27,640	69.36	31,210	77.76	34,990
12	26.18	11,780	37.70	16,970	51.31	23,100	58.91	26,510	67.02	30,160	75.66	34,040	84.83	38,170
13	28.37	12,770	40.84	18,380	55.59	25,030	63.82	28,720	72.61	32,670	81.97	36,880	91.90	41,350
14	30.55	13,750	43.98	19,790	59.86	26,950	68.73	30,930	78.19	35,180	88.27	39,720	98.97	44,530
15	32.73	14,730	47.13	21,210	64.14	28,880	73.64	33,140	83.78	37,700	94.58	42,560	106.0	47,720
16	34.91	15,710	50.27	22,620	68.42	30,800	78.54	35,340	89.36	40,210	100.9	45,390	113.1	50,900
17	37.09	16,690	53.41	24,040	72.69	32,730	83.45	37,550	94.95	42,720	107.2	48,230	120.2	54,080
18	39.27	17,680	56.55	25,450	76.97	34,650	88.36	39,760	100.5	45,230	113.5	51,070	127.2	57,260
19	41.46	18,660	59.69	26,860	81.24	36,580	93.27	41,970	106.1	47,750	119.8	53,900	134.3	60,440
20	43.64	19,640	62.84	28,280	85.52	38,500	98.18	44,180	111.7	50,270	126.1	56,750	141.4	63,620
21	45.82	20,620	65.98	29,690	89.80	40,430	103.1	46,390	117.2	52,780	132.4	59,590	148.4	66,800
22	48.00	21,600	69.12	31,110	94.07	42,350	108.0	48,600	122.9	55,300	138.7	62,420	155.5	69,980
23	50.19	22,490	72.26	32,520	98.35	44,280	112.9	50,810	128.5	57,810	145.0	65,260	162.6	73,160
24	52.37	23,570	75.40	33,930	102.6	46,200	117.8	53,020	134.0	60,320	151.3	68,100	169.6	76,340
25	54.44	24,550	78.55	35,350	106.9	48,130	122.7	55,230	139.6	62,840	157.6	70,940	176.7	79,530
26	56.73	25,530	81.69	36,760	111.2	50,050	127.6	57,430	145.2	65,350	163.9	73,770	183.8	82,710
27	58.91	26,510	84.83	38,180	115.5	51,980	132.5	59,640	150.8	67,860	170.2	76,610	190.9	85,890
28	61.10	27,500	87.97	39,590	119.7	53,900	137.5	61,850	156.4	70,370	176.5	79,450	197.9	89,070
29	63.28	28,480	91.11	41,000	124.0	55,830	142.4	64,060	162.0	72,890	182.8	82,280	205.0	92,250
30	65.46	29,460	94.26	42,420	128.3	57,750	147.3	66,270	167.6	75,400	189.2	85,120	212.1	95,430

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In gold placer operations the giant cuts the gravel from the bank and washes it into the sluices in which the gold is recovered. This method may be used in recovering commercial sand and gravel, but it may also be modified. Instead of washing the gravel to a sluice through which it would be carried to the washing plant, the gravel may be washed to a sump previously cut in the bedrock. From the sump it can be picked up and sent on to the plant by a dredge pump. By the same arrangement a clamshell crane could pick up the material to any type of transportation equipment. By the use of bedrock sumps within reach of the sweeping range of the giant, the floor of the excavation can be kept level. If sluices are used the floor must rise as it advances to accommodate the necessary grade for the sluice. Sluices are usually built in 10- to 16-foot sections averaging 12 feet long and from 1 to 5 feet wide. The grade ranges from 1/8 to 1 1/2 inches to the foot (1.0 to 12 1/2 percent) but is ordinarily 1/4 to 3/4 inch to the foot (2.1 to 6.2 percent).

Where no natural head is available, water must be pumped to the giant under pressure.

Capacity

The capacity of a hydraulic giant in terms of the number of cubic yards or tons of gravel it will remove is incapable of exact computation.

In placer mining water is commonly measured in miner's inches. A miner's inch is the equivalent of a flow of 1 1/2 cubic feet per minute over a period of 24 hours.

The duty of a miner's inch in hydraulicking is defined as the number of cubic yards of gravel which it can break down and move to the sluice in 24 hours. The factors affecting this duty are so varied that at only a few mines can direct comparison be made. For the same reason an average duty cannot be computed. The duty appears to be highest in large-scale operations. Tight or cemented gravel is difficult to break down, requiring higher pressure or excess quantity; a high bank takes less water per cubic yards than a low one; a flat bedrock requires an excessive quantity for sweeping the material to the sluice; angular rock and gravel with flat or large boulders requires more water; clay-bound gravel requires excessive washing; high pressure is more effective than low for cutting or sweeping; and one large nozzle has usually been found more effective than two smaller ones using the same quantity of water.

According to Gardner and Johnson,[6] the calculated duty at 40 placer mines in 1932 ranged from 0.4 to 4.3 cubic yards per miner's inch, including wash water.

Wimmler[7] tabulates water duty at Alaskan placer mines at 0.25 to 10.0 cubic yards per miner's inch.

6/ Gardner, E. D., and Johnson, C. H., Placer Mining in the Western United States: Inf. Circ. 6787, Bureau of Mines, 1934, 89 pp.

7/ Wimmler, N. L., Placer-Mining Methods and Costs in Alaska: Bull. 259, Bureau of Mines, 1927, p. 139.

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In few placer mines cited by either authority, however, was the total water used exclusively in the cutting giants. In most mines water used for hydraulic elevators, for tailings stackers, or for ground sluicing was included. Wimmler states that where it is unnecessary either to elevate the gravel or stack the tailings a duty of 3 to 4 cubic yards per miner's inch should not be uncommon. In a single instance he cites a 10-cubic-yard duty in stripping frozen muck where no elevating or stacking was required. He also accounts for the low water duty at placer mines as due to the low bedrock and sluice-box grades and generally low water pressures.

As sand and gravel operators do not customarily use the miner's inch as a measure of water flow, this paper confines calculations to cubic feet or gallons.

The miner's inch is the equivelent of a flow of $1\frac{1}{3}$ cubic feet or $11\frac{1}{4}$ gallons per minute for 24 hours.

Since a flow of 1 miner's inch of water is estimated to produce from 3 to 10 cubic yards of gravel in 24 hours, a flow of 1 cubic foot or $7\frac{1}{2}$ gallons per minute will produce from 2 to 6.7 cubic yards in 24 hours or from 0.083 to 0.28 cubic yards per hour.

In sand and gravel practice it is customary to estimate the water duty as similar to that required in hydraulic pumping, namely, the gravel carried is 10 percent by volume of the material pumped.

On this basis 0.083 to 0.28 cubic yard of gravel per hour with a flow of 1 cubic foot of water per minute is the equivelent of 3.7 to 12.6 percent solids by volume.

Correlating placer-mine duty with sand and gravel experience, one can safely assume that in hydraulicking sand and gravel the duty of a flow of 1 cubic foot of water per minute will range from 0.08 to 0.25 cubic yard of gravel per hour.

This capacity range is of the order of 1 to 3, but the great divergence of local conditions does not permit closer estimation.

Application of this range of duty to tables 27, 28, and 29, with due weight given to the conditions existing at individual installations, will enable the operator to compute the equipment necessary to provide the proper quantity with approximate accuracy. However, as previously stated, the pressure required cannot be calculated but must be based on experience.

To illustrate the use of the tables a few examples have been worked out, as follows:

Example 1.- Assume it is desired to produce 300 tons (200 cubic yards) per 10-hour day from a heavily compacted bed of gravel. Water for hydraulicking is available at a distance of 5,000 feet and 200 feet above the proposed location of the giant. The contour of the surface, however, is such that the

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water must be piped the whole distance since equivalent elevation is not available closer. This means that ditches cannot be used to bring the water part way to the deposit. It also means that the effective head on the giant will be less than 200 feet. As less than 200 feet of head is available and the gravel is heavily compacted, the pressure may not be sufficient to cut the gravel from the bank without blasting or the use of an excessive quantity of water.

Three hundred tons per day means 30 tons or, roughly, 20 cubic yards per hour, and since the gravel is cemented only a minimum duty can be expected from the water.

The water required for hydraulicking is $\frac{20}{0.08}$ = 250 cubic feet or, 1,875 gallons of water per minute; that is, 4.17 cubic feet or 31.25 gallons per second.

Table 27 shows that a 3-inch nozzle with 10-inch base will supply 5 cubic feet per second at 200 feet effective head, or 4.4 cubic feet at 150 feet effective head.

From table 29 an 18-inch pipe line will supply 5.3 cubic feet per minute at a velocity of 3 feet per second.

From table 28 the friction loss in an 18-inch pipe at 3 feet per second will be 0.27 feet for each 100 feet of pipe line.

It is assumed the 18-inch pipe is brought to within 200 feet of the giant and that 10-inch pipe is used from there to the giant for easier handling.

From table 29 (by interpolation) the velocity required through the 10-inch pipe to supply 5 cubic feet per second is 9.2 feet per second.

From table 28 the corresponding friction loss will be 3.83 feet of head per 100 feet of pipe.

On the basis of 200 feet of 10-inch and 4,800 feet of 18-inch pipe, the loss in friction head in delivering 5 cubic feet per second will be as follows:

	Feet
200 feet of 10-inch pipe @ 3.83	7.66
4,800 feet of 18-inch pipe @ 0.27	12.96
Total friction-head loss	20.62

The effective head at the giant will then be 200 - 20.62 = 179.4 feet.

At this effective head the giant will deliver 4.8 cubic feet per second, which is in excess of the 4.17 cubic feet required assuming that a minimum water duty could be expected.

Provided no water were lost and assuming the 179.4 feet of head provides sufficient pressure to cut the compacted gravel, the flow in the sluice to plant or pump would be composed of 96.9 percent water and 3.1 percent solids by volume at the assumed water duty.

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Example 2.- Assume the same conditions as in example 1, except that the surface contour is such that water can be brought to within 1,000 feet of the giant in ditches and still be 200 feet above the giant.

Table 24 shows that a ditch having a bottom width of 3 feet, top width of 6 feet, and depth of 1.5 feet will discharge 6.55 cubic feet per second at a velocity of 0.97 feet per second if constructed on a slope of 4 feet per mile. Since the flow is 57 percent more than the assumed requirements such a ditch should be ample, and since 4,000 feet will be required 1,000 cubic yards of excavation will be necessary in its construction. The intake end must be 3.06 feet above the high-water level in the reservoir from which the pressure is obtained.

Let us assume that 24-inch pipe will be used from the reservoir to within 200 feet of the giant and 8-inch pipe from thereon. This requires a 3-inch giant with an 8-inch base which from table 27 will supply 5.13 cubic feet of water per second at 200 feet of effective head.

Table 29 (by interpolation) shows that a 24-inch pipe will supply 5.13 cubic feet of water per second at a velocity of 1.63 feet per second, and table 28 shows that the friction-head loss at this velocity is 0.074 feet per 100 feet of pipe.

Table 29 shows that an 8-inch pipe will deliver 5.13 cubic feet per second at a velocity of 14.7 feet per second, and table 28 shows that the friction-head loss at this velocity is 11.65 feet per 100 feet of pipe.

On this basis the loss in head due to friction will be as follows:

	Feet
800 feet of 24-inch pipe @ 0.074	0.592
200 feet of 8-inch pipe @ 11.65	23.30
Total friction-head loss	23.892

The effective head will be 200 - 23.892 = 176.1 feet.

At this head the giant will deliver 4.8 cubic feet of water per second.

If the 200 feet of 8-inch pipe were replaced by 10-inch pipe the loss in head would be as follows:

	Feet
800 feet of 24-inch pipe @ .074	0.592
200 feet of 10-inch pipe @ 3.83	7.66
Total	8.252

The effective head would be 200 - 8.25 = 191.75 feet and the flow 4.96 cubic feet per second. The substitution of the 10-inch for the 8-inch pipe would increase the volume of water delivered by the giant but, by decreasing friction loss, would have increased the effective head at the giant by 191.75 - 176.1 = 15.65 feet, or 6.8 pounds per square inch pressure and thus make the giant that much more effective for cutting the hard bank.

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Example 3.- Assume the same conditions as in example 1, except that the gravel is loose and contains no clay or boulders, or in other words offers opportunity for a maximum water duty.

The water required for hydraulicking will be $\frac{20}{0.25}$ = 80 cubic feet or 600 gallons of water per minute; that is, 1.33 cubic feet or 10 gallons per second.

Table 27 shows that with an effective head of 200 feet a 1 3/8-inch nozzle will supply 1.06 cubic feet of water per second and a 2-inch nozzle 2.26 cubic feet. The smaller nozzle is inadequate, and the larger one throws considerable excess water. The probable solution lies in selecting a nozzle tip between these two sizes. A 1 5/8-inch nozzle tip with a 6-inch base under an effective head of 200 feet would throw 1.485 cubic feet per second.

Tables 28 and 29 show that a 10-inch pipe will supply 1.5 cubic feet at a velocity of 2.76 feet per second with a friction-head loss of 0.43 foot per 100 feet of pipe.

If 4,800 feet of 10-inch and 200 feet of 6-inch pipe are used tables 28 and 29 show that the 6-inch pipe will supply 1.5 cubic feet per second at a velocity of 7.64 feet per second with a loss in friction head of 4.51 feet per 100 feet of pipe.

The friction head loss would then be as follows:

	Feet
4,800 feet of 10-inch pipe @ .43	20.64
200 feet of 6-inch pipe @ 4.51	9.02
Total	29.66

The effective head at the giant will be 200 - 29.66 = 170.34 feet and the flow 1.365 cubic feet per second or slightly more than required.

The solids would compose a little less than 11 percent of the flow in the sluice, and since the gravel was assumed to be loose no difficulty should be experienced here.

The available head might easily be more than required, however, under the assumed conditions. In such case, the head could be lowered by a pressure-reducing valve in the supply line or by bringing the water part way in ditches to a reservoir at a lower elevation near the giant.

Example 4.- Assume the same conditions as to gravel and tonnage requirements as in example 3, but assume that the land surface is flat and consequently there is no water supply affording a natural head. Hydraulic water must be pumped to the giant from a source 5,000 feet distant and from an elevation 20 feet below the giant. Assume further that 100 feet of effective head is required at the giant.

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The head against which the pump must operate will then be the effective head at the giant, plus the friction head in the supply line, plus 20 feet of static lift, plus, say, 15 feet of suction head at the pump.

As in example 3, 1.33 cubic feet of water will be required per second.

Table 27 shows a 2-inch nozzle on a 6-inch base will supply 1.6 cubic feet per second under 100 feet of effective head. This is more than required, but it is assumed that this selection is made.

Table 29 shows an 18-inch pipe will deliver 1.77 cubic feet per second at a velocity of 1 foot per second, and table 28 shows the friction-head loss to be 0.04 foot per 100 feet of pipe at this velocity.

Assuming the 18-inch pipe is brought to within 200 feet of the giant and 8-inch pipe used from there on, tables 29 and 28 show the velocity in the 8-inch pipe would be 5 feet per second and the friction-head loss 1.54 feet per 100 feet of pipe.

On this basis, the loss of head due to friction would be as follows:

	Feet
4,800 feet of 18-inch pipe @ 0.04	1.92
200 feet of 8-inch pipe @ 1.54	3.08
Total friction-head loss	5.00

The total head against which the pump must operate will then be as follows:

	Feet
Effective head at giant	100.0
Friction loss	5.0
Static lift	20.0
Suction head	15.0
Total	140.0

The pressure at the pump would be 60.62 pounds per square inch.

A flow of 1.6 cubic feet per second is the equivalent of 720 gallons per minute. The indicated pump requirements would be a 6-inch single-stage centrifugal pump operating at 1,750 r.p.m. and driven by a 40-hp. motor.

The gravel under these conditions would compose 9.4 percent by volume of the flow in the sluices.

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INFORMATION CIRCULAR

DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SAND AND GRAVEL EXCAVATION--PART 2: POWER SCRAPER, SLACKLINE CABLEWAY EXCAVATOR, AND HYDRAULIC GIANT[1]

By J. R. Thoenen[2]

INTRODUCTION

This circular is part 2 of the third subject (entitled "Excavation") of a series summarizing the technical problems involved in the production and preparation of sand and gravel. Part 1 discussed the use of power shovels, draglines, and excavator cranes. This paper discusses the use of the power scraper, slackline cableway excavator, and hydraulic monitor, and part 3 will discuss the use of various types of dredges. Subsequent papers in the series will discuss the use of haulage equipment, the application of both excavating and haulage equipment to various types of deposits, and operating costs.

THE POWER SCRAPER

The power scraper is a younger member of the various forms of gravel excavators. It is a mechanized enlargement of the slip scraper and other scrapers which depend upon animals for power and has a greater range of operation from a single set-up than any other excavation unit except the slackline cableway excavator.

The mechanical construction of the power-scraper installation bears little resemblance to that of other types of excavators discussed in part I. Briefly, it consists of a head and tail mast or tower between which the load and return cables are stretched. (See fig. 3.) The scraper is attached to these cables and is drawn back and forth by them. Thus the power scraper is a dual unit, each part of which may be moved independently of the other.

At the dumping end the head mast may be a single timber or steel structure set on a permanent foundation. The head mast may also be built into and form a part of the treatment plant, or it may consist of a self-propelled wooden or steel structure set on trucks moving in either direction at right angles to the drag cables.

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At the loading or tail end the structure may be a simple low mast guyed to anchorages set in the ground. Like the head mast, it may also be mounted on self-propelled trucks operating on tracks which may or may not parallel those at the head end, or the tail end may consist of a block attached to any point on a bridle cable, each end of which is anchored. Either head or tail support may be mounted on a chassis moving on caterpillar traction.

Further flexibility is obtained by anchoring deadmen around the periphery of the excavation, from which guide blocks may be used to throw the scraper into the bank out of line between head and tail supports as needed.

The motive power is supplied by a two-drum scraper hoist mounted at the head end. The power may be either steam, gasoline, Diesel, or electric motor. In the usual installation, the loading cable is wound on one drum of the hoist whence it is led to a sheave at the top of the head mast. From there it passes on in the direction of the tail mast and is fastened to a chain or wire-rope bridle on the front end of the scraper. The return or pull-back cable is fastened to the rear end of the scraper, runs to a sheave at the tail anchorage, thence back in an unguided span to a second sheave at the top of the head mast, and then to the second drum on the hoist. (See fig. 3, plan.)

One man operates the scraper by manipulating the hoist drums. As the scraper is being hauled toward the head mast by the loading cable on one hoist drum, the other drum is paying off the pull-back cable. When the scraper reaches the dumping position the operator reverses the hoist and the pull-back cable returns the scraper to the digging position. For each fixed position of head and tail supports the scraper travels in a straight line between them except as modified by auxilliary guide blocks. Thus the digging area for two such fixed points is only a little more than the width of the bucket at the bottom of its troughed path but may be nearly the full distance between head and tail masts. As the excavated trough deepens and material from its sides caves into the path of the scraper, the scraping width is extended. The tail support, however, may be moved laterally independent of the head mast as needed, and for each such move a new scraping area is made available. This movement of the tail end may be accomplished in three ways. With a bridle support the tail sheave may be moved on the bridle. With a movable tail tower the tower itself may be moved laterally. By the third method the tail support remains stationary and the digging area is changed by threading the pull-back cable through a snatch block fastened to a shifting cable leading to an anchorage off center from the line between head and tail supports. This cable may be attached to a hand winch or a third drum on the hoist and shortened at will. Thus the scraper may be forced to dig into the bank at either side and widen the excavation.

The customary installation just described may be varied by returning the pull-back cable through a sheave or other device fastened on top of the scraper. This breaks the long span of the cable from tower to tower and gives the operator more accurate control in spotting the scraper at the desired point. By braking the loading cable while the pull-back cable is returning

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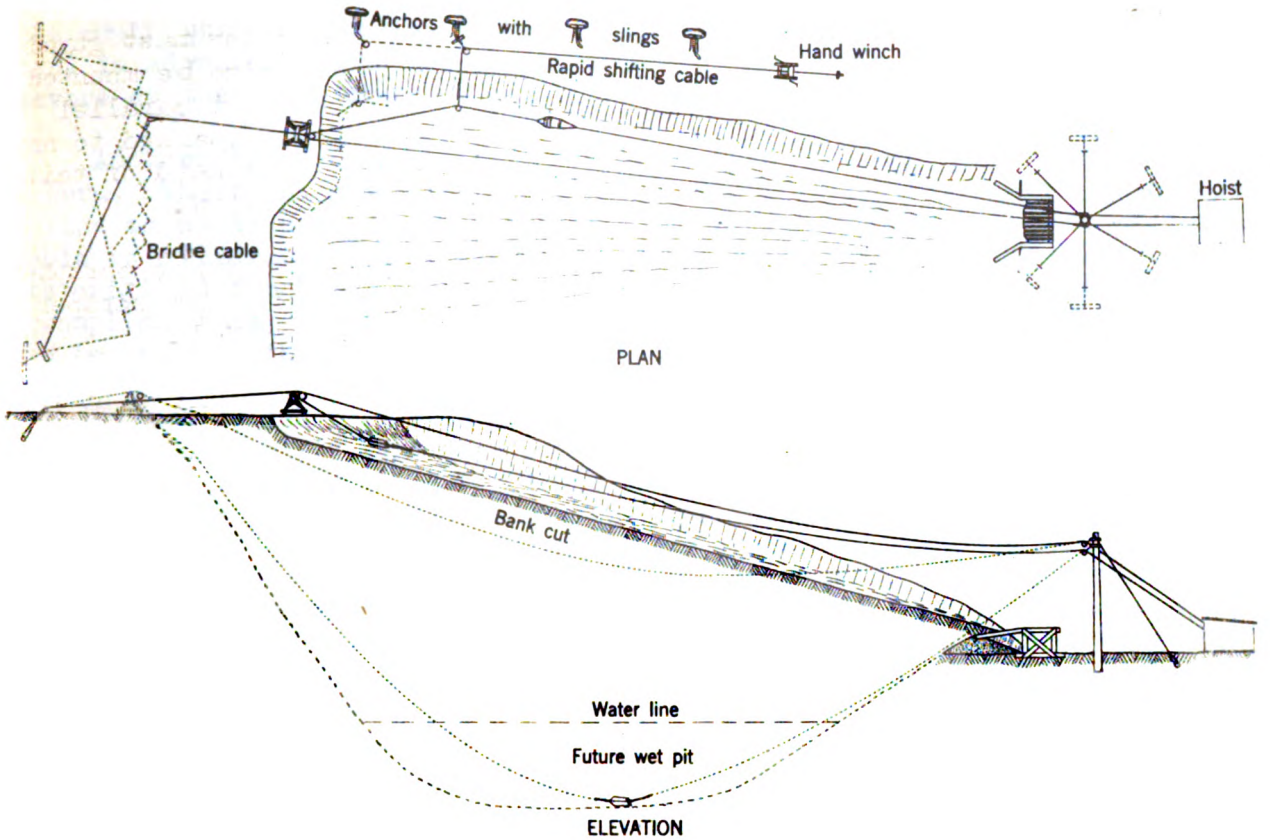

Figure 3.—Power scraper.

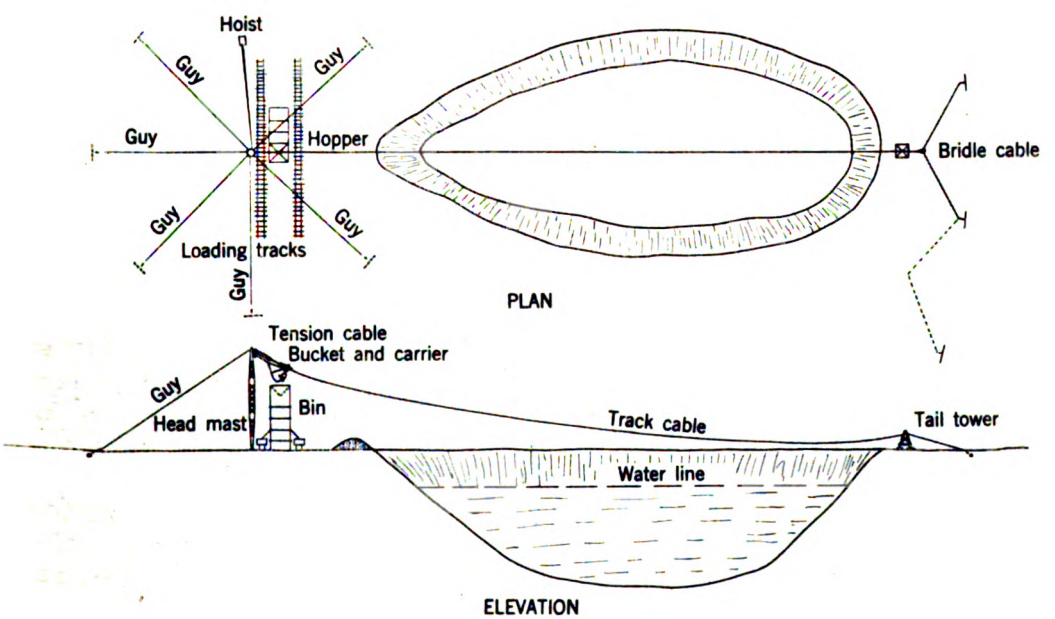

Figure 4.—Slackline cableway excavator.

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the empty scraper, the latter may even be lifted in the air. Such close control is advantageous in long spans or when high towers are used but is very severe on the hoist clutches and brakes.

Another type of installation is often used for long spans or high head towers. Where the head tower is high and the tail support is at a lower elevation so as to provide considerable incline from head to tail, the pull-back cable is eliminated and a track cable substituted. The loading cable retains its original function, but the scraper is returned to the pit by gravity. To accomplish this, the drum vacated by the pull-back cable is used to manipulate the tension on the track cable.

A rope is led from this drum to the sheave at the top of the head mast and is then threaded through a set of double or triple blocks. The track cable is fastened to the outer block of this set. The other end is attached to the tail support. Thus the operator can regulate the tension on the track cable with one drum on the hoist while the other drum controls the loading cable. The scraper is hung from a carriage containing one or more sheaves free to travel on the track cable. Starting with the scraper at the digging point and the track cable slack, the operator pulls the scraper towards the head mast by the loading cable. As the scraper nears the dump, he tightens the track cable which throws the scraper high in the air while dumping. He then releases the loading drum, and with the track cable tight and the scraper suspended in the air the carriage and scraper return by gravity to the pit. As the digging point is approached the operator slackens the track cable lowering the scraper to the excavation.

Excavation may proceed by the various methods in any direction radial from the head mast. Excavations may be of any shape, and when both head and tail mast are movable they may proceed along the long axis of a comparatively narrow excavation. Thus the excavation may be circular with the head mast in the center or rectangular with head and tail supports at either end or side.

The power scraper may be used to remove overburden as well as to dig gravel. In removing overburden a small area may be stripped first and the material dumped at the head mast to form an incline, up which gravel may be dragged later to the dumping point. When this small area is stripped the scraper may remove the gravel. When the gravel excavation is complete the tail block may be set back and the overburden removed from a second and larger area and dumped into the first pit.

Eventually a distance between head and tail masts will be reached beyond which it becomes uneconomical to operate, but until then the power scraper does its own hauling and requires no transportation unit to serve it. No fixed rule can be set as to what this economic haulage distance may be. It will vary with the size of the scraper, the power applied to the load cable, the speed of load and pull-back cables, the type of material to be dug, the method of excavation, the design and weight of the scraper, and the tonnage required in a given time.

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When the limiting haulage distance has been reached, a second scraper unit may be installed to extend the excavations and the first used purely as a transportation unit. Any other type of transportation unit may be used if preferred. This includes portable conveyors, auto trucks, locomotives and cars, or aerial trams. When such equipment is used the dumping point of the scraper is usually a ramp built out of timber or fill material over a hopper which discharges directly to the transporting vehicle or to a bin from which the unit is loaded by gravity.

The drag scraper may be used to remove material from either dry or wet pits. The scraper operates between head and tail supports which are ordinarily placed on the ground surface. By the use of a slack cable the scraper can be used to reach considerable depth. (See fig. 3, elevation.) Large boulders resist digging by the scraper as they do with the dragline, although with the longer digging trench of the scraper an accumulation of boulders can be spread out over a longer area with more chance of being picked up. Boulders larger than the scraper cannot be removed by it.

The tail support need not be on the same level as the head mast. Thus the upper portion of a pit may be excavated dry if desired. The tail mast can then be lowered to the water level and the lower portion of the pit excavated wet.

Likewise, the tail pulley may be placed considerably above the head mast. The scraper then operates down hill. A track cable may be used in such installations by mounting a third drum on the hoist. Gravity return cannot be used. With such an installation material caving from the bank does not interfere with scraper operation but becomes advantageous. The caving of high banks is not a menace with this type of equipment. In fact, bank caving is often used to increase production by excavating high banks in the shape of inclined troughs. Material caving from the sides of the trough is dragged ahead of the scraper to the foot of the incline. In this way material can be moved in quantities greater than the actual capacity of the scraper during the course of its great extension or hauling distance. The accumulations at the foot of the incline may then be scraped to the dumping point with a shorter haul requiring less time.

Structural Limitations

The power scraper operates from the surface of the ground, and like the dragline the only portion actually entering the excavation is the scraper and its attached cables. Therefore, it can be used with equal facility in either dry or wet pits.

Since the tail support may be either below or above the head mast, the scraper can be used to excavate from either deep pits or high banks.

The lateral or horizontal reach of the scraper is limited by the economic hauling distance for a particular scraper size. This will vary with different deposits and conditions. The maximum hauling distance for the

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smallest scraper will be about 200 feet, and the hauling distance will increase with the size, although not in direct ratio. In straight-line operation the average hauling distance will be one half the maximum span between head and tail supports. When operated radially, the average haul will be about 70 percent of the span, due to the greater quantity of material contained in the outer area of the circular segment.

The depth below ground to which the power scraper may reach also varies with local conditions. Where head and tail supports are at about the same elevation the digging depth will range from 10 to 20 percent of the maximum span. Where the tail support is below the head mast the digging depth may be increased by that difference of elevation at the extreme outer end, tapering back to the surface at the head mast. The maximum height of the tail support above the head mast is roughly 50 percent of the maximum span.

The height to which material may be raised before dumping also depends upon local conditions and requirements. If the tail mast is a part of the treatment plant it will exceed the roof level enough to accommodate the sag in the loading cable. If the building is constructed to permit a gravity flow through the plant the dumping height may be greater than it would ordinarily. In such instances it is necessary to construct a trough through which the scraper can operate in rising above the ground surface.

In ordinary operation power scrapers dump 20 to 50 feet above the ground level. The dumping point is usually one half to two thirds the height of the head mast.

The power scraper has no means of directly forcing its bucket into the ground at a designated point as has the shovel. Like the dragline it depends upon the design and weight of the scraper to dig. However, owing to the greater length of inhaul cable it has even less control of the point of entry than the dragline. In starting operations the scraper may follow a rather erratic path over the surface of the deposit. This is quickly corrected, however, by subsequent trips in which the scraper digs its own path in a straight line towards the head mast.

The design of the power scraper itself varies greatly with the ideas of the manufacturers. It is not within the province of this report to discuss the superiority or inferiority of one design over that of another, but certain differences in construction may be mentioned.

All power scrapers are bottomless. Some are rectangular, some semicircular, and others crescent shaped. Some have no top covering, some have a partial top, and others are completely covered. Some are designed to dig with one side only, while it is claimed with others that they dig equally well with either side up. It is claimed that all types will dig until the pressure of the entering material against the cover or upper side lifts the scraper; it then rides on its load without further digging. If through rough handling a part of the load is lost, the reduced pressure immediately starts the bucket to digging again. For further details the reader is referred to the manufacturers' catalogs.

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Primary power for power scrapers may be either steam, gasoline, Diesel, or electric motor. Since the power requirements of power scrapers are peculiarly similar to those of hoisting engines, many prefer steam or electric power for the larger sizes. Table 14 presents the working ranges and speeds of power scrapers of various sizes according to manufacturers' catalogs. Table 15 gives the power units ordinarily furnished with scrapers of different sizes.

Service Equipment Required

As usually supplied, the power scraper may be classed as semiportable equipment. The head mast ordinarily remains stationary for considerable periods of time, although the tail anchorage may be shifted daily. The power unit is placed at or near the head mast and does not require a constant shifting or power cables, water lines, or fuel lines.

The scraper is itself a transporting unit within the limits of its span. It can deliver to other types of haulage equipment when necessary. Autotrucks, cars, and aerial-tram buckets can be used. When the scraper delivers to these types of equipment it is usually supplied with a bin at the head mast from which the haulage units are loaded by gravity. If a second scraper is used for haulage the first delivers to a storage pile on the ground and the second scrapes from this pile. The introduction of a loading bin or storage pile at this point makes the digging scraper independent of the service unit to the extent of the capacity of the bin or pile. Thus a less exacting service by the haulage unit is necessary because during its absence the scraper can dump to bin or pile.

Capacity

Theoretically the capacity of a drag scraper depends upon the size of the scraper, the speed of load and pull-back cables (or gravity return), and the distance between digging point and dump.

The working capacity depends upon all of these elements and others such as weather conditions, the character of the material to be dug, whether excavation is from wet or dry pit or bank, the design and weight of the scraper, the service rendered by the accessory haulage unit, and the location and efficiency of the operator.

Calculating theoretical capacity on the basis of scraper size, cable speeds, and drag lengths without allowance for any delay would give a capacity figure of no practical value. All the other elements that affect working capacity must be evaluated and their influence represented in any formula designed to determine a capacity figure which can be used by an operator. Elements affecting working capacity are for the most part intangible, and they are not susceptible to reduction to mathematical precision. Therefore, in the writer's opinion drag-scraper capacities cannot be calculated by formulas.

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TABLE 14. - Power-scraper working ranges

Scraper capacity, cubic yards	Maximum span, feet		Dumping height, feet		Digging height mechanical return, feet	Digging depth, feet		Loading speed, f.p.m.		Outhaul speed, f.p.m.		Gravity return speed, average, f.p.m.
	Mechanical return	Gravity return	Mechanical return	Gravity return		Mechanical return	Gravity return	Minimum	Maximum	Minimum	Maximum	
1/3	200	500	20	48	100	20	80	175	200	320	400	900
1/2	300	600	20	58	150	30	90	175	200	320	400	900
3/4	300	700	25	64	150	30	130	200	260	330	600	900
1	350	800	25	72	175	35	140	200	260	330	600	900
1 1/2	400	1,000	30	88	200	40	160	200	225	-	600	900
2	400	1,200	30	93	200	40	180	200	225	-	600	900
2 1/2	450	1,400	30	96	225	45	200	200	225	-	600	900
3	450	1,500	40	106	225	45	210	200	225	-	600	900
4	500	1,500	40	104	250	50	210	200	-	-	600	900
5	500	1,500	40	102	250	50	210	200	-	-	600	900
6	600	1,500	50	100	300	60	210	200	-	-	600	900
8	600	1,500	50	98	300	60	210	200	-	-	600	900
10	700	1,500	50	96	350	70	210	200	-	-	600	900
12	700	1,500	50	94	350	70	210	200	-	-	600	900

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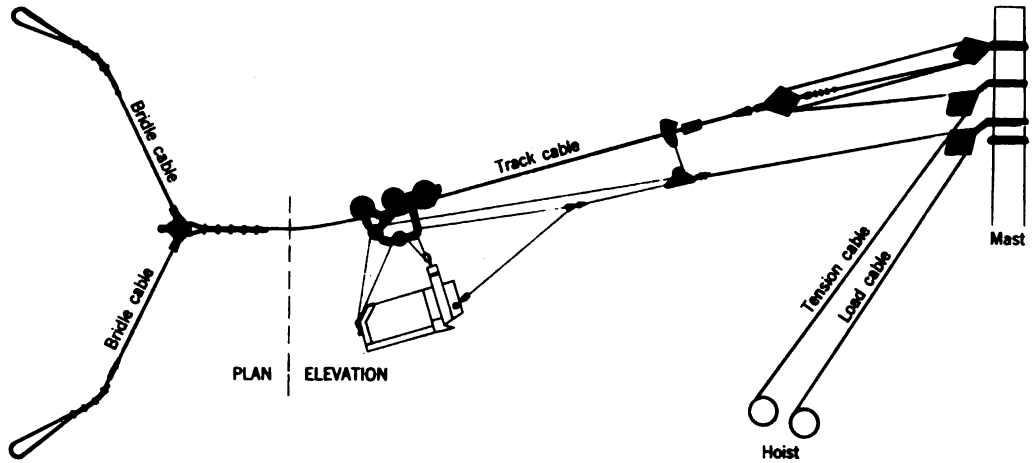

Figure 5.—Slackline cableway excavator, bucket and cable assembly.

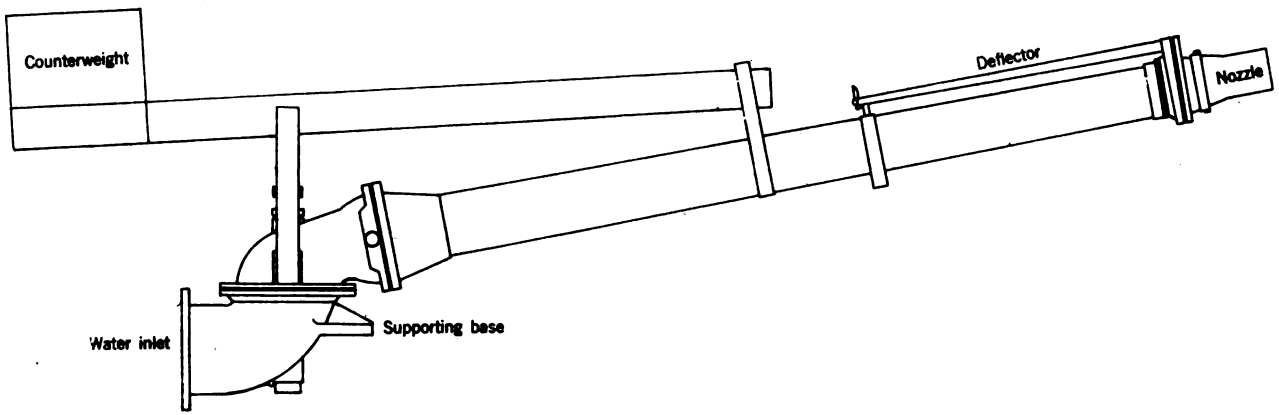

Figure 6.—Hydraulic giant or monitor (diagrammatic, no scale).

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